FORESTRY

THE JOURNAL OF THE SOCIETY OF FORESTERS OF GREAT BRITAIN

Edited by R. W. V. PALMER

VOLUME XXXIV : NUMBER 2

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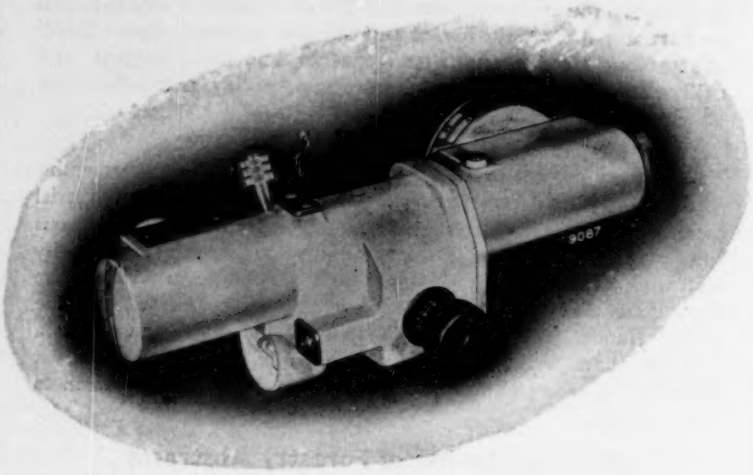

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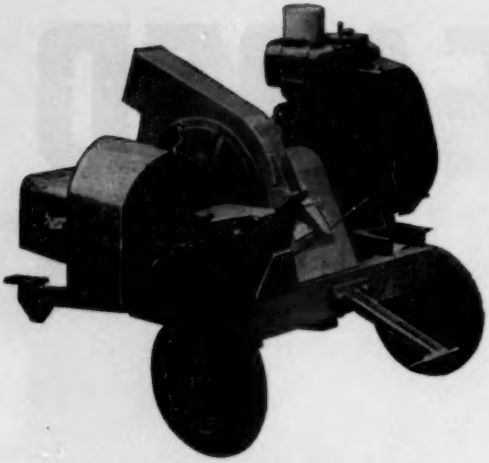

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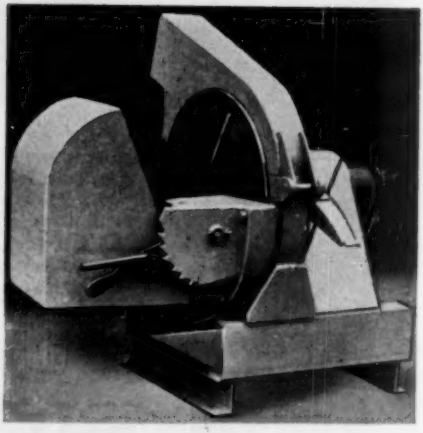

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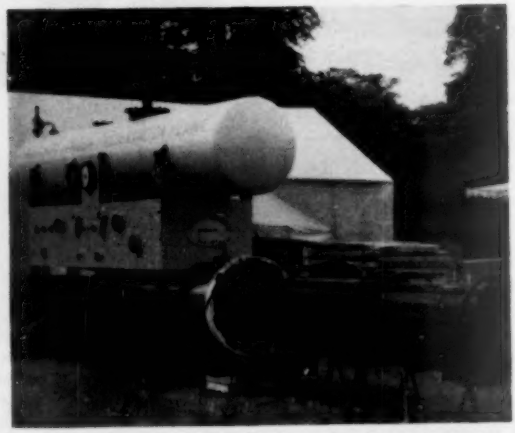

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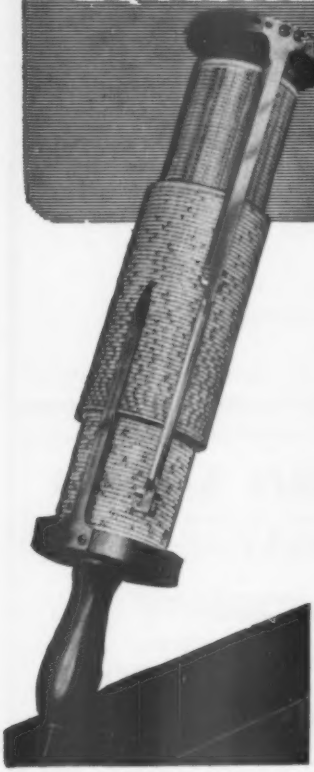

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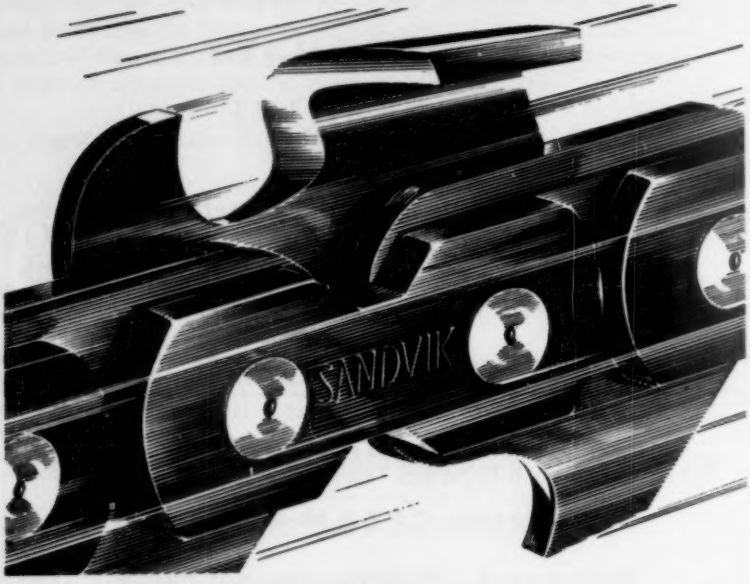

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J. M. CABORN

THE smooth, rounded profile of the Lammermuir Hills, typical of much of the Southern Uplands, affords relatively little 'natural' shelter. Valleys canalize the wind, not with the intensity experienced in the deeply-cut valleys of mid-Wales, for example, but appreciably nevertheless. Higher up the slopes the wind largely clings to the contour and, compared with leeward aspects, there is often as much if not more shelter for sheep and low crops where windward faces flatten out towards the crest of the characteristically flat-topped ridges.

Heavy snow-storms create frequent anxiety; otherwise winter temperatures are not severe, but there is a considerable chance of a wind to reduce the temperature effectively. Dr. K. L. Blaxter of the Hannah Research Institute, in a recent address to the Royal Society of Arts, showed that at Eskdalemuir (Dumfriesshire) the likelihood of winds exceeding 13 m.p.h. associated with temperatures between 41° and 50° F. is somewhat more than 1 in 3, so that farm stock is exposed to an environmental stress greater than that produced by still air at freezing-point for probably a quarter or a third of the year. Though less for the Lammermuirs, perhaps, shelter for livestock is clearly important. In addition, dry easterly winds prevalent in the spring inhibit early growth on pastures and on the upland arable ground, which the soils derived from Upper Old Red Sandstone and glacial drift allow up to 900 ft. and more.

Shelter may be beneficial, but few estates in the district can boast the 700 acres of plantations which gave rise to this article.[1] Established at intervals since 1896, when the original estate of Whitchester had only one shelterbelt of importance, these 700 acres include the replacement of war-time fellings and 100 acres feued to the Forestry Commission. Apparently, their presence has made a significant contribution to the productivity of the author's property. For example, on Cranshaws Farm, the highest-lying on the 8,000-acre estate, stock values have risen from less than £5,000 in May 1896 to about £35,000 in May 1960. Dr. Landale allows a multiplier of 3·3 to correct 1896 values to the present day, based on current auction prices and past records. This shows a more than twofold increase in productivity over this period, and it is suggested that a quarter to a third of this improvement can be attributed to the effects of shelter, though it would doubtless be more accurate to say that these have been more in the nature of indirect benefits than the 'direct result of shelter'.

This remarkable increase of between 30 and 40 per cent., credited to shelter, is bound to arouse scepticism. Financial benefits accruing from shelterbelts on stock farms are always elusive and intimately bound up with a particular system of management. However, other practical results are undeniably advantageous even

[1] S. E. A. Landale. 'Shelter for Profit in the Hills of South-East Scotland.' *Scottish Agriculture*, vol. xl, no. 4, Spring 1961. H.M.S.O. Price 1*s*. 3*d*.

if they defy expression in simple cash terms: cattle have increased from 24 head to 181; ewe hoggs now winter at home, a tremendous advantage with the present shortage of wintering grounds against the competition from increased dairying and more stock on the hills, not forgetting high transport costs; earlier lambing and calving can be achieved with safety and fewer losses; and Hill Cheviots on the lower ground have given way to the heavier North Country type, without a reduction in numbers.

One suspects that the present prosperity enjoyed by several farms in south Scotland, which were well furnished with shelterbelts and woodlands by eighteenth- and nineteenth-century landowners, owes a good deal to an improved environment that provided a foundation for other improvements. Normally, reliable evidence to this effect is not available; one can merely speculate. But Dr. Landale presents a case much nearer our own time and with a certain amount of positive evidence. Amongst this, the photograph of a bleak Whitchester House in 1881 compared with the oblique aerial shot of the same house in 1948, now framed in sheltering trees, provides the sort of dramatic comparison that is usually associated with the U.S. Great Plains or the Canadian prairies. This 'before and after' comparison is the more impressive on account of the time scale: the transformation has come about very largely within the present century.

Outside the policies at Whitchester, even *Rhododendron ponticum* and common laurel struggle against the exposure. Yet, inside, various exotics flourish and in a nearby sheltered field young racehorses have been outwintered successfully.

The planting policy has been to provide shelter where and when it is most required in the normal course of farm management. This involves countering the winds prevailing when the fields are stocked: between north-east and south-east in spring, between south and west in summer, and between north-west and north-east in winter. To provide shelter for large fields advantage has been taken of the ground formation to give a sheltered area greater in extent because it falls away parallel with the wind. Just how much this increases the range of shelter has never been established, but it is usually accepted that this does happen.

The siting of belts in upland country is generally difficult and one has to avoid generalization as regards principles that may be adopted. However, the arrangement suggested for sheltering a typical 'cleugh' or gully, carved out by burns rising well up the hillsides, merits attention from farmers in similar topography. Leeward slopes with gradients less than 1 in 4 or 1 in 5 seem to give no shelter of their own; consequently belts along the contour find their greatest use in such undulating country and these are suggested for sheltering the cleughs. Another interesting feature, unfortunately not described in the article, is the effect of the south-west arm of the three-legged belt shown on the accompanying map as Compt. 65. Jutting out on a steep shoulder at the junction of a short valley open to the north and another lying roughly north-west to south-east, the near-mature Scots pine, thin amongst the trunks, affords ideal shelter against northerly winds flowing down the smaller valley and breaking over the shoulder. In principle, the arrangement is somewhat reminiscent of the 'Cardigan bank', a free-growing hawthorn hedge on a high earth mound, that is prized by many Welsh farmers for

its excellent shelter. Would a denser plantation on the shoulder have the same influence on the wind-flow pattern? These are points which foresters advising farmers should consider.

Shapes and sizes of belts at Whitchester vary widely, but Dr. Landale recommends 70 yards as a reasonable minimum width. For shelter alone on soils that support trees without much difficulty, this is an over-estimate; balanced with a productive aspect, it is another story. Where does one draw the line then? The answer should be that there is no line and the widths of from 1 to 5 chains that have been variously recommended for upland belts are purely arbitrary figures. Once it is accepted that a fairly dense shelterbelt is essential or inevitable, there seems little to choose between belts 2 chains wide and others 20 chains as far as shelter is concerned. The availability of land decides, and this is not solely a question of its site value but also of the role this area assumes in the farmer's scheme of management. Poor land can still occupy a key position in the system. Probably it would be no bad thing if this item of *width* were to be dropped from advisory literature at least; it becomes too prominent. Farmers as well as foresters know the costs of fencing; let the farm dictate the width and the forester provide a satisfactory shelterbelt accordingly, whether the width is 20 yards or two hundred.

Reference to tree species is brief, but Dr. Landale's adherence to fast-growing conifers is explained in that 'rapid growth in the first 10 years is even more important . . . than development of fine timber in the second twenty years'. Quick establishment and, consequently, early shelter tend to be overlooked by all but the horticultural users of shelterbelts but there is no doubt that initial effort and extra expense to aid establishment, such as proper preparation of the ground, the use of fertilizers on poor sites, coupled with some fast-growing species and regular weeding afterwards, pay dividends. But at the same time there needs to be some provision for stability and permanency: the fast growers are rarely the most hardy or most permanent. Toughening up the exposed margins with wind-resistant species, as suggested, may suffice to check windblow in the narrower belts. Something more is necessary in the wider belts. Dr. Landale clearly appreciates the potential hazards of planting pure, so it is somewhat surprising that he has not made more use of hardwoods and sycamore particularly; these generally find a good market in the Borders.

The Whitchester case is not an example of providing an endless series of traditional long shelterbelts; it is much more an example of the successful integration of forestry with agriculture in roughly a 1:10 ratio. The upland farms absorb these scattered plantations quite easily and even increase their output once the shelter becomes effective. Looked at in this light, it is a commendable enterprise. There should be more Whitchesters.

A KEY TO BEECH (*FAGUS SYLVATICA*, L.) ASSOCIATIONS ON CHALK UPLANDS IN ENGLAND, DEVISED BY RAY BOURNE

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SUMMARY

A chart prepared by the late Ray Bourne is reproduced showing the relationships between soils, ground vegetation, natural regeneration, and ecological woodland associations of the beech (*Fagus sylvatica*, L.) on chalk upland sites in southern England. This hitherto unpublished chart represents the result of extensive field observations by the originator and has been found to be of much practical value. It is reproduced to ensure that a valuable piece of work is not lost to future foresters.

DURING his lifetime the late Ray Bourne was acknowledged to have a unique and probably unsurpassed knowledge of the beechwoods of the Chilterns and other upland chalk regions of southern England. He had devoted a very great deal of intensive study to this subject as a forester and forest manager.

When Bourne died in 1948 he unfortunately left behind little in the way of published notes embodying the conclusions which he had reached as the results of his many years of intimate association with the beechwoods of this region. He had, however, come to several very definite and useful practical conclusions regarding the past history of the British beechwoods, the various ecological associations in which beech occurs, the relationships between soils and the ground flora, and the degrees of ease or difficulty in securing natural regeneration of the beech.

This information Bourne condensed and summarized in a characteristic chart or diagram which is reproduced as Fig. 1.

The original chart, which will be familiar to some of Bourne's former students, was produced in colour but this has had to be modified to enable reproduction in black and white.

Six principal soil types are differentiated. These soil types form the hub or basis of the classification and are grouped into Rendzinas, Brown Earths, Degraded Brown Earths, and Podsols.

The characteristic plants of the ground vegetation associated with these soil groups are shown, using seven indicator species and giving the comparative frequency of each. The chart then links the soil and ground vegetation types with natural regeneration of beech to show in which conditions natural regeneration can be expected to be easy or difficult to obtain and establish.

The natural woodland associations ecologically associated with each of these

Chalk Upland Regions

KEY TO BEECH ASSOCIATIONS

Types and Sub-types

REFERENCE

Tree Layer	Ground layer
Beech	Polytrichum
Oak	Luzula
Birch	Scilla
	Rubus
Ash	Sanicula
	Arum
Yew	Mercurialis

FIG. 1

main soil and vegetation types are shown in the outer ring. Five tree species are represented, including beech, and again the relative frequency of each is indicated. Three main ecological woodland communities are recognized, viz. Beech–Oak–Ash, Beech–Oak–Birch, and Beech–Ash–Yew. These in turn are subdivided to show the comparative quality of the beech to be expected in various conditions of soil and ground vegetation, and finally seven 'types' and ten 'sub-types' of beechwood are differentiated for the region.

It is, of course, true that no system of classification can take into account all the factors characteristic of such a complex and dynamic concept as the forest ecosystem, but the practical value of field observations is unquestioned and the writer has frequently found this chart to be reliable. It is because of its usefulness and the possibility that it may be lost to future foresters that it is reproduced with gratitude to its originator.

ACKNOWLEDGEMENT

I wish to express my thanks to Mr. J. E. Garfitt for supplying a copy of Bourne's original chart, from which Fig. 1 was prepared.

VARIATION IN TRACHEID LENGTH WITHIN THE RING IN *PINUS RADIATA* D. DON

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SUMMARY

1. Measurements of tracheid length from a series of tangential sections confirmed the usual pattern of change in mean length through the growth ring and a similar pattern in a false ring.

2. Cell-series traced through these sections showed that most pseudo-transverse divisions of the cambium occur at the ring boundary. Similar divisions in mother cells in the early wood appear to be the major factor reducing mean length in early wood and in wide rings. There is appreciable intrusive growth in the late wood tracheids.

INTRODUCTION

VARIATION within the growth ring is of particular interest in connexion with the relation between width of ring and cell length. A general pattern—short in the early wood rising to a maximum in the late wood—seems to be typical of both hardwoods and softwoods, but to be derived from such different growth processes that the relation to rate of growth may well be reversed in the two groups. It has been shown by Chalk, Marstrand, and Walsh (1956) and Myint Aung (1960) that such a pattern can be produced in storied woods entirely by intrusive elongation of the fibres, without any change in the mean length of the fusiform initials. In the conifers, on the other hand, it appears to have been generally assumed that intrusive growth is negligible and that the most probable cause might lie in the occurrence of most pseudo-transverse divisions of the cambium at the end or beginning of the growth ring (Bannan, 1955). Bannan (1960*a*) has recently shown this not to be the case in *Thuja occidentalis* L. and has stressed the importance of division in the mother cells (1960*b*).

The following small investigation was undertaken before Bannan's most recent results were available, with the hope of throwing some light on the relative importance of these factors, and it is satisfactory to note that his main conclusions have been independently confirmed as valid for another species.

MATERIALS AND METHODS

The material consisted of a disc of fast-grown *Pinus radiata* from the base of a 14-year-old tree from a plantation in Kenya. From a radial strip two successive rings were selected, one of them containing a false ring; successive tangential sections 15 μ thick were cut through these rings.

Every tenth section of the early wood and every fourth late wood section was mounted so that the distance between the sections examined was 150 μ and 60 μ in the early and late wood respectively. A total of 120 sections were examined.

The method used for measuring tracheid length was that described by Ladell (1959). Briefly this consists of counting the number of cell tips between parallel lines of known distance apart on the projected image of a tangential section.

Attempts were made to follow the progeny from single fusiform initials on radial sections and on split radial surfaces, but irregularities of the grain in this fast-grown material and particularly distortion of the tips of the cells rendered these methods unsatisfactory. It was, however, possible to trace changes in radial files of cells by examining the series of tangential sections used for measuring tracheid length.

RESULTS AND DISCUSSION

(i) *The General Pattern Within the Ring*

Variation of mean length conformed with the pattern found by other investigators, being low at the beginning of the ring, rising with the formation of late wood to a maximum near the end of the ring, and then decreasing markedly to a short length again in the succeeding early wood. This can be seen in Fig. 1, particularly in the part covered by sections 1 to 47. The increase towards the end of the ring may be relatively abrupt as at section 21, or gradual, as in the rise from section 47 to section 59. This increase in the mean length of the late wood tracheids is often accompanied by a local increase in the number of rows of tracheids as seen between any two rays in transverse sections. The intruded tips of the cells are visible as a radial row of small cells that first appears at the beginning of the late wood and disappears after a few cells in the early wood.

TABLE I

Variation of Numbers of Radial Rows of Tracheids in Early and Late Wood in Rings A, B, and C

	Early wood 'A'		*Late wood 'A'*	*Early wood 'B'*		*False late wood 'B'*			*Early wood 'C'*	*Late wood 'C'*
Sampling zone .	1	2	3	4	5	6	7	8	9	10
Number of rows .	5·5	6·8	7·8	7·2	6·2	7·4	7·2	7·4	6·2	7·9
Number of samples	10	10	18	10	18	10	10	10	10	10

This is shown in Table I, which gives the mean figures obtained for the number of cells between the same pairs of rays at different positions in the rings illustrated in Fig. 1. For example, sampling zone 3 is from the late wood marked 'A' and sampling zone 4 from the beginning of the succeeding early wood. It will be seen from the table that the number of rows is consistently higher in each late wood zone and that the additional rows persist to some extent into the first sample from the early wood. In the late wood 'A' (sampling zone 3) there are

FIG. 1. Mean tracheid length across two growth rings compared with the development in length of cells derived from particular cambial initials.

7·8 rows; the number drops to 7·2 in zone 4 at the beginning of the early wood and to 6·2 in the middle of the early wood.

The change from the long late wood tracheids at the end of the ring to the shorter early wood cells at the ring boundary is not as abrupt as is claimed by Bisset and Dadswell (1950) for *Pseudotsuga taxifolia* and *Pinus radiata* and by Amos, Bisset, and Dadswell (1950) for *Eucalyptus gigantea*, but is relatively gradual, extending, for example, for nearly a millimetre beyond the ring boundary at section 35. The method used in this investigation is particularly suited to the study of this point, as the sections can be accurately located and can be examined to see whether the cells consist of early or late wood tracheids. The material, however, differs from that grown under temperate conditions in that the outer edges of the late wood are not very sharply defined, as is the case when the growing seasons are separated by a definite and prolonged dormant period. It will be seen in Fig. 1 that the change to early wood is very similar both after the true ring ending at section 35 and after the late wood of the false ring ending at section 77.

The magnitude of the decrease at the end of the ring is about 19 per cent. of the longer cells between sections 35 and 47 compared with 10 per cent. for *P. radiata* and 19 per cent. for *Pseudotsuga* as derived from the figures in Bisset and Dadswell (1950).

A false ring was included in the study for comparison with a true ring. Tracheid length in the early wood 'B' started normally and rose from a minimum until section 62, where late wood ('B') began to be formed. This late wood was not completed and the tissue reverted to early wood at about section 77. Later (section 108) more late wood was formed ('C') and the ring was finally completed at section 119. Tracheid length thus behaved approximately as if there were two separate rings, being low in each early wood and high in each late wood; in the middle of the late wood of the false ring there was a distinct reduction in length (about 16 per cent.) that could be correlated with a zone of cells with slightly thinner walls.

(ii) *The Behaviour of Individual Cells*

Changes in the radial rows of cells produced by single cambial initials were traced by drawings from tangential sections. The results confirmed the observation of Bannan (1956) that growth in length is achieved by growth at the tips and that such growth may occur at one end only.

It was also observed that elongation is most rapid immediately after a pseudo-transverse division of the cambial initial and in the late wood at the end of the ring. It is possible that the former is due to the elongation of the cambial initial and the latter to intrusive growth in the tracheid. Occasionally the tip of a row of tracheids was seen to change from one side of a ray to the other.

Pseudo-transverse divisions of the cambium occurred mainly near the ring boundary. Bannan (1951) found that in *Chamaecyparis* and *Thuja* divisions occur towards the end of the growing season, but in the present investigation they occurred commonly also at the beginning of the next season's growth. Transverse divisions were also observed to occur in the mother cells in the early wood, as has been recorded by Bannan (1955).

Following a pseudo-transverse division of the cambium, the two halves may each elongate till they reach or exceed the length of the original cell, but commonly one-half decreases in length and ultimately disappears; in some cases one-half divides again and both of these halves may disappear. This again is in line with Bannan's observations, but, whereas he suggests a cycle of 4 years before the original length is regained, in the present investigation the period appeared to be shorter. It must be noted, though, that the cells selected for drawing were all below the mean length and the period might well be greater for longer cells. This bias towards the shorter cells was not appreciated till the investigation was completed; it was doubtless due to the greater ease with which shorter cells could be traced. The time-lag between division and resumption of the original length may be of importance in connexion with the influence of rate of growth. It can be plausibly argued that any sudden increase in the number of pseudo-transverse divisions resulting from an increased rate of growth should, if there is a time-lag of 4 years before regaining the original length, reduce the mean length at least temporarily. Bannan's recent results (1960*a*), however, show that there is no such relation and that reduction of length in the early wood is mainly due to the formation of pseudo-transverse divisions in the mother cells.

Four cell-series selected at random were traced through 230 sections from the late wood of one ring to the late wood of the next. Changes in length were of an unexpectedly high order, the maximum often being 100 per cent. higher than the minimum. Three of the four cells showed sudden decreases of this order in the early wood, but not simultaneously, and only one of these occurred at the very beginning of the early wood. It was very noticeable that approximately the original length was regained in these three series with equal abruptness later in the early wood. Such changes must almost certainly have been the result of divisions in the mother cells, as indeed was suggested by examination of the sections. The magnitude of the changes and their occurrence in three out of the four series examined thus confirm that pseudo-transverse division in the mother cells may be the most important factor causing the typical reduction of mean tracheid length in the early wood of this species also, and if, as Bannan (1957) has suggested, the incidence of transverse divisions in mother cells tends to rise with rate of growth, this factor may well constitute the principal mechanism by which mean length is reduced in wide rings. That such divisions do not occur simultaneously at the beginning of the early wood may also explain why the minimum tracheid length does not occur at the ring boundary itself, but a little later.

Six further cell-series were traced through ninety sections from the later-formed early wood of one ring through the late wood and into the succeeding early wood of the next ring. It was expected that they would show a steady increase in length in the late wood and so confirm the evidence of intrusive growth in the late wood given in Table I. Such an increase occurred in five out of the six series, but was greater in magnitude than was expected, the mean for the five cells rising from 3·3 to 4·0 mm., an increase of about 23 per cent.

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TRACHEID AND FIBRE LENGTH IN TIMBER
A REVIEW OF LITERATURE

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SUMMARY

The literature is reviewed under six main headings: variation within one growth ring; variation outwards from the pith at any one level; variation with increasing height in the tree; the effect of rate of growth; the relationship with cambial increment; genotypic and ecotypic variations.

The reviewer points out that the results obtained are often contradictory. He suggests that two particular aspects of the subject require further attention: the exact role of the terminal meristem in determining cell length and the relationship between the terminal meristem and the cambium.

There is a bibliography of 123 items which has been made as complete as possible to June 1961.

IN contrast to the large number of articles relating to variation in the length of the tracheary cells in wood, there have been but one or two comprehensive reviews of published literature. The review by Spurr and Hyvärinen (1954*a*) represented an important contribution though even it was not fully comprehensive. Several minor reviews have appeared at the beginning of certain articles, but these generally contain references to only the better-known papers; one independent bibliography has been published (Bisset, 1949).

Previous investigations on tracheid and fibre length fall naturally into two main groups. In the period 1872–1932 most of the investigations were carried out in Germany, though after 1910 there were also contributions from North America. These investigations carried out on both gymnosperms and angiosperms yielded interesting but sometimes apparently contradictory results. The foundation of the study of tracheid and fibre-length variation was laid by Sanio (1872) who presented his results of studies on Scots pine (*Pinus sylvestris*) in a set of five conclusions which, for some time now, have been regarded as 'Sanio's Laws'.

From 1932 to 1948 only a few studies were made of tracheid and fibre length and it was not until the last decade that the second intensive series of investigations took place. This era is marked by a large number of investigations on commercial timbers resulting in an abundance of information regarding cell-length variation in most of the softwoods and a few hardwoods, notably *Populus* and *Eucalyptus*. These studies have been carried out in most countries and vary considerably in the sampling procedures and conclusions. The greatest contribution to the literature has been made by the Australian team led by Dr. Dadswell, though results as significant, or even more so, have been presented by a few independent workers in both eastern and western countries.

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The review of literature can be conveniently subdivided into a number of sections corresponding to the different fields of investigations.

The variation in tracheid or fibre length within one growth ring

Significant differences in the length of tracheids or fibres in the springwood and summerwood were first recorded by Bertog (1895). He was followed by Gerry (1915, 1916) who found that the summerwood tracheids of Douglas fir (*Pseudotsuga taxifolia*) were consistently shorter than those of the springwood; Lee and Smith (1916), however, recorded contrary results in the same species. Similar results to those of Lee and Smith were recorded by Kribs (1928) for Jack pine (*Pinus banksiana*), Neergaard (1928) for Norway spruce (*Picea abies*), Chalk (1930) for Sitka spruce (*Picea sitchensis*), in which the summerwood tracheids were 12 per cent. longer, and by Helander (1933) for Scots pine and Norway spruce.

A number of more recent investigations have also yielded information on the relative length of the spring and summerwood cells. Thus Anderson (1951—*Abies concolor*, *A. procera*, and *Pseudotsuga taxifolia*), Bosshard (1951—*Fraxinus excelsior*), Saya (1955—*Ailanthus altissima*), Kramer (1957—*Pinus taeda*), Scaramuzzi (1957*b*—*Eucalyptus*), and Hejnowicz and Hejnowicz (1958—*Populus tremula*) all report a general increase in the length of the summerwood cells. More specific information is presented by Kuziel (1953) who stated that the summerwood cells of *Populus* are from 20–33 per cent. longer, by Liese and Ammer (1958) who reported an average increase of 15–20 per cent. for *Populus* × *robusta*, and by Schultze-Dewitz (1959) whose results indicated that the summerwood cells in Norway spruce were as much as 17–25 per cent. longer than the springwood tracheids, the difference being greater in the southern radius and in sub-dominant trees.

In most of these investigations only two samples were removed from each ring; these comprised the springwood and summerwood and, whilst this may represent an adequate sampling procedure for the comparison of different rings, it is certainly not intensive enough for the determination of the variation in cell length within a growth ring.

Intensive investigation of variations within the ring was first carried out by Bisset and Dadswell (1949), employing a simple but ingenious sampling procedure, whereby thick tangential serial sections (80 and 120 microns) were cut by microtome. Average lengths were obtained at ten to twenty points across the ring in *Eucalyptus regnans*, and a distinct pattern of fibre-length variation was presented. The length of fibres in the springwood decreased towards the centre of the ring and then increased towards the end of the ring, at which point it was maximal for the ring.

This sampling procedure was again employed in the determination of the patterns of variation in a large number of angiosperms and gymnosperms (Bisset and Dadswell, 1950). Where distinct growth rings were present the average cell length of the summerwood was always greater than that of the springwood, the percentage difference being lower in the gymnosperms than in the angiosperms.

The Australians have also shown that cell length on the 'sun' side of the tree is from 0·05 mm. to 0·35 mm. greater than on the 'shade side' of the tree (Liese and

Dadswell, 1959). Liese and Ammer (1958) record a decrease of 2–4 per cent. on the south-facing side of stems of *Populus* × *robusta*.

Wardrop (1949), however, like Gerry (1915), recorded a relative decrease in the length of the summerwood tracheids in two rings of *Pinus radiata*. Such a result should be accepted with caution because only two rings were studied. Furthermore, in a later paper Bisset and Dadswell (1950) found that the summerwood tracheids were longer than those of the springwood.

Chalk and Ortiz (1961) confirm the pattern of variation in *Pinus radiata* recorded by Bisset and Dadswell (1950) with a reservation that the change in tracheid length from the summerwood of one ring to the springwood of the next is gradual rather than abrupt; this result may be related to the fact that the timber examined by Chalk and Ortiz was grown in the tropics and displayed indefinite annual ring boundaries.

In an intensive study of fibre length within a growth ring of *Pterocarpus angolensis*, Chalk *et al.* (1955) showed that while the average length of the tracheids in the latter half of the ring was greater than that of the first half, the maximum length occurred somewhere in the middle of the ring.

Vasiljevic (1955) carried out an intensive study of the length of successive cells in four rings from 70–90-year-old trees of *Picea abies*. The average length of cells in tangential rows increased from the beginning to the end of the growth ring, though in tracing outwards any one particular radial file of cells, length occasionally decreased at the end of the growth ring.

Dinwoodie (1960) has shown that in Sitka spruce, except for the first three rings from the pith in which tracheid length increases linearly across the ring, the last-formed tracheids in the ring are 5–11 per cent. longer than those at the beginning of the ring, and 17–30 per cent. longer than those of minimum length in the centre of the ring. In studying the pattern of tracheid-length variation in normal and in 'double' or 'false' rings he came to the conclusion that the location of minimum tracheid length occurred at the boundary between springwood and summerwood. There was an apparent correlation between the rate of height growth and the rate of decrease in tracheid length across the springwood, though this requires further investigation.

The only other attempt to explain the variation in tracheid length in terms of growth rate was carried out by Amos, Bisset, and Dadswell (1950), who related variations in cell length in *Eucalyptus gigantea* to the change in rate of diameter growth throughout the season.

A considerable number of investigators have examined the length of cells in reaction wood and there is general agreement that in this abnormal tissue the length of the cells is reduced considerably (Lee and Smith, 1916; Dadswell and Wardrop, 1949; Bisset and Dadswell, 1950; Jones, 1957). It is not yet clear what factors are involved in this reduction of length (see Wardrop and Dadswell, 1950; Spurr and Hyvärinen, 1954*b*).

Thus studies of cell-length variation within the growth ring have provided much useful information. While it would appear that the average length of the summerwood cells is longer than that of the springwood, the variation across

the ring is seldom linear in mature timber and it is possible to find both very long and very short cells in the middle of the ring.

The variation in length outwards from the pith at any one level in the tree

Every investigator of this aspect of length variation has recorded the same general trend, namely that cell length in the ring nearest the pith is very short (0·5–1·5 mm. in conifers, 0·1–1·0 mm. in broad-leaved species), but increases rapidly outwards in the first few rings; after this, the rate of increase declines until a maximum tracheid length is obtained which is generally from three to five times greater than the initial length: considerable disparity appears, firstly as to whether this length increase outwards is associated with increasing ring number or with linear distance from the pith, and secondly as to whether tracheid length, after increasing initially, remains constant or fluctuates.

A number of investigators have concerned themselves purely with the study of plant anatomy and have not related variations in anatomical features to such factors as age or rate of growth—Bailey and Tupper (1919), Rendle and Clarke (1934), Misra (1939), Bannan (1941, 1942), Pillow (1952), Susmel (1952), Esau (1953), Saya (1955), Kennedy and Smith (1959), and Ho and Liu (1959).

A second series of investigators record a general relationship between tracheid length and the relative age of the ring. Chalk (1930) who investigated the variations in tracheid length in *Picea sitchensis*, Kaeiser and Stewart (1955) and Kaeiser (1956) on *Populus deltoides*, Kennedy (1957) on *Populus trichocarpa*, and Jackson (1959) on *Pinus taeda*, all record an increase in length with increasing number of rings from the pith. Lack of information as to whether the rate of increase outwards from the pith is constant or variable can possibly be related to either the sampling of very young material (Kennedy) or to the adoption of a low-intensity sampling procedure (Chalk, Kaeiser and Stewart, Kaeiser).

Several investigators have recorded, at a given number of rings from the pith, the attainment of a maximum tracheid length, after which tracheid length remained constant or very nearly constant in successive rings. Sanio (1872) recorded a constant tracheid length in *Pinus sylvestris* after the maximum had been reached between the 25th and 60th rings from the pith. He was so impressed with the complete lack of variation in length in old timber that he suggested the possibility of using tracheid length for purposes of identification. The findings of Sanio for Scots pine have been supported by the results of Mell (1910) for *Pseudotsuga taxifolia*, Pritchard and Bailey (1916) for *Carya ovata*, Bailey and Faull (1934) for *Sequoia sempervirens*, Bethel (1941) with *Pinus taeda*, Nilsson (1943) for *Picea abies*, Bisset and Dadswell (1949) with *Eucalyptus regnans*, Hata (1949) with *Pinus densiflora*, and Dadswell (1958) with *Pinus radiata*.

The point at which maximum tracheid length is reached appears to vary both with the species and possibly also with the rate of growth. The wide range in the number of rings from pith to the ring containing the maximum cell length is apparent from Table I opposite.

Not all investigators, however, are in agreement with the findings of Sanio and his supporters who postulated the existence of a constant cell length. An actual

decrease in fibre length towards or at the outside of the tree was reported by Hartig (1885) for *Fagus sylvatica*, by Lee and Smith (1916) for *Pseudotsuga taxifolia*, and by Helander (1933) for *Pinus sylvestris* and *Picea abies*. This decrease in cell length may possibly be due to the onset of senescence when the general efficiency of the tree is gradually reduced. Both Shepard and Bailey (1914) and Bailey and Faull (1934) recorded decreases in cell length at an advanced age, the latter workers finding a decrease in *Sequoia sempervirens* from the 380th to the 410th ring.

TABLE I

		Number of rings from pith to ring containing maximum tracheid length	*Total number of rings in tree sampled*
Pinus sylvestris	(Sanio, 1872)	25–60	—
Pinus radiata	(Bisset and Dadswell, 1949)	10	50
Pinus radiata	(N.Z. Forest Res. Inst. 1953)	14 or less	45
Pinus caribaea	(Jackson and Green, 1958*a*)	15–25	65
Pseudotsuga taxifolia	(Lee and Smith, 1916)	50	—
Picea abies	(Schultze-Dewitz, 1959)	70–80	85
Picea sitchensis	(Dinwoodie, 1960)	120	260
" "	" "	180	300, 360
Tsuga occidentalis	(Harlow, 1927)	100	160
Sequoia sempervirens	(Bailey and Faull, 1934)	210	410
Carya ovata	(Pritchard and Bailey, 1916)	20–25	—
X *Populus euramerica*	(Scaramuzzi, 1955)	6–8	10
X *Populus robusta*	(Liese and Ammer, 1958)	10	34

A slow, but progressive, increase in length after the initial 'maximum' had been reached was recorded by Gerry (1916), who found that length continually increased throughout the rings of a 455-year-old Douglas fir tree. Kramer (1957) and Jackson and Green (1958*a*), working with 65-year-old trees of loblolly and slash pine (*Pinus caribaea*) respectively, found that after the initial 'maximum', length continued to increase slowly to the outside ring. Desch (1932) also recorded that fibre length was still increasing after 100 years in alder, birch, poplar, sycamore, and beech.

Further investigations based on Sanio's findings were undertaken by Shepard and Bailey (1914) and Bailey and Shepard (1915) on *Pinus palustris*, *P. strobus*, and *Abies concolor*. They found that, after a maximum tracheid length had been attained, there was considerable fluctuation in length. In one particular tree studied, this variation in length occurred until the 230th ring. A study of the effect of site factors on tracheid length in *Thuja occidentalis* by Harlow (1927) showed that considerable variation in length occurred after the maximum length had been reached. Similar results were recorded by Kienholz (1931) for *Pinus contorta*, and by Liang (1948) for *Larix*. Fluctuation in tracheid length, after a maximum had occurred, was also found by Dinwoodie (1960) in an investigation on tracheid-length variation in sixteen 120–360-year-old trees of *Picea sitchensis*; fluctuations could be related to the width of ring.

Liang (1948) working with the genus *Larix* found, however, that the effect of age was not significant when removed from the regression of length on a measure of the perimeter increment of the cambium.

A number of investigators have related tracheid-length variation to the linear distance from the pith. Anderson (1951) determined the relationship between length and distance from the pith in *Abies concolor*, *A. procera*, and *Pseudotsuga taxifolia*. This relationship could be expressed mathematically for each tree without regard to age or level in the trunk. Kuziel (1953), in four species of *Populus*, has also related the variation in fibre length to distance from the pith, while Govindavajalu and Swamy (1955) found a similar relationship for both the septate and non-septate fibres in *Pithecolobium dulce*. Hejnowicz and Hejnowicz (1958) have stated that fibre and vessel length in one tree of *Populus tremula* is related to the total number of cambial generations, which can be expressed by the linear distance from the pith. This relationship was the same at all levels in the trunk, whereas considerable disparity occurred between different levels when the cells were related to age. However, the relationship only applied when the bottom two metres of the stem were ignored on the grounds that the rooting system was having some effect on tracheid length.

Recent work by Stevens (1959) and Loach (1959) at Oxford on *Pinus caribaea* and Grenadier apple respectively indicate that when tracheid length is related to distance from the pith rather than age, there is less variation in tracheid length, and specimens with a higher tracheid length in the pith retained this relative position in adult wood. In seedling material of *Pinus radiata*, however, Hartley (1960) found no correlation between final tracheid length and distance from the pith.

The results of two recent investigations have done much to resolve the problem of whether tracheid-length variation is a function of age or distance from the pith. Elliott (1960) in reporting studies on a 41- and a 68-year-old Sitka spruce tree has concluded from a comparison of correlation coefficients that the effect of age is significant only in the early years; as the tree matures the effect of age is superseded by that of ring width.

Dinwoodie (1960), working independently in Aberdeen on the same species, concluded from the results obtained from a series of multivariate analyses carried out on six Sitka spruce trees from North America, ranging in age from 260 to 360 years, that in the first fifteen rings from the pith the effect of age on tracheid length appears to be more important than distance from the pith. In rings greater in number than fifty from the pith, distance from the pith can account for more of the variation in tracheid length than age. In the intermediate zone (rings 16–49), there is no difference in importance between age and distance on tracheid length. The results obtained in these analyses, namely that somewhere between the 16th and 49th ring there appears to be a change in the importance of factors influencing tracheid length, were supported by the results from additional material.

In concluding this aspect of tracheid-length variation, it would appear that the maximum tracheid length does not occur till an advanced age (200–300 years)

after which there is a period of maximal length before decreasing in extreme old age (400–500 years). In young plantation-grown material there is an *apparent* maximum tracheid length occurring between 10 and 20 years depending on the species.

Superimposed on this basic pattern of length variation are small vicissitudes which, as will be seen in a later section, are the result of variations in rate of growth; uniformity of growth rate will give the smooth tracheid-length curves reported by Sanio and his supporters.

It would appear that the relationship between tracheid length, age, and distance from the pith is more involved than originally estimated and it now looks as if both factors are involved in determining cell length, their relative significance varying outward from the pith.

The variation in tracheid length with increasing height in the tree

There would appear to be considerably less contradiction between the results of previous investigations regarding the variation of tracheid length with increasing height in the tree. This relationship can be conveniently studied from two different aspects which correspond with two different vertical sequences of rings in the tree. Thus, either a single ring may be followed upwards, or, rings at a fixed number of rings from the pith may be traced upwards.

With regard to the variation in tracheid length within a growth ring, considerable evidence has accumulated to show that length increases upwards for a certain distance before decreasing progressively to the top of the tree, the average length of the tracheids at the top of each ring generally being less than that of the tracheids at ground level. The position of maximum tracheid length in each ring, therefore, will be located at progressively higher levels as successive rings are formed.

This relationship between cell length and the height of each growth sheath was first put forward by Sanio (1872) for *Pinus sylvestris*. He related the position of maximum tracheid length to that part of the trunk where the colour and texture of the bark changed from being relatively thick and greyish brown to a yellowish-brown scaly rind. This pattern of tracheid-length variation has been verified by many later workers for a wide range of species—Hartig (1892) for *Picea abies*, Bertog (1895) for *Abies alba* and *Picea abies*, Omeis (1895) for *Pinus sylvestris*, Bailey and Shepard (1915) for *Pinus palustris*, *P. strobus*, and *Abies concolor*, Mork (1928) for *Picea abies*, Chalk (1930) for *Picea sitchensis*, Desch (1932) for species of *Alnus*, *Betula*, *Fagus*, *Populus*, and for sycamore (*Acer pseudoplatanus*), Rendle and Clarke (1934), Bethel (1941) for loblolly pine, Hata (1949) for *Pinus densiflora*, Bisset and Dadswell (1949) for *Eucalyptus regnans*, Entrican (1957) for *Pinus radiata*, Dep. For. Queensland (1958) for *Araucaria cunninghamii*, Hejnowicz and Hejnowicz (1958) for *Populus tremula*, and Schultze-Dewitz (1959) for *Picea abies*. A number of workers have recorded the percentage height at which tracheid length is maximal in each growth ring. Helander (1933) recorded that in *Pinus sylvestris* and *Picea abies* the maximum cell length occurred between 15 and 40 per cent. from the ground. For the genus *Larix*, Liang (1948) recorded a range

of 20–40 per cent., while for loblolly pine Jackson (1959) and Jackson and Green (1958*a*) record a percentage of 30. Elliott (1960) found that the maximum tracheid length in a single stem of *Picea sitchensis* occurred at one-third the height of the tree. Only Hartig (1885—*Fagus sylvatica*), Stauffer (1892—*Quercus robur*), and Pritchard and Bailey (1916—*Carya alba*) recorded a progressive decrease in the length of fibres with increasing height in the tree.

Less evidence is available regarding the variation in tracheid length upwards in rings at a fixed number from the pith. With the exception of the first ring from the pith, tracheid length has been found to increase with increasing height up to some point in the stem, after which length remained constant (Lee and Smith, 1916—*Pseudotsuga taxifolia*, and Chalk, 1930—*Picea sitchensis*). Some workers have found a slight decrease in length towards the top of the tree (Kribs, 1928—*Pinus banksiana*; Bisset and Dadswell, 1949—*Eucalyptus regnans*; Hejnowicz and Hejnowicz, 1958—*Populus tremula*).

In the ring nearest the pith, tracheid length remained constant or varied extremely little up the tree (Bisset and Dadswell, 1949; Hata, 1949; Div. For. Queensland, 1958; Jackson, 1959).

In all these investigations sampling up the tree has been carried out on a height basis taking no account of the position of the nodes or length of the internodes. Only two series of cell-length investigations (namely N.Z. For. Res. Inst., 1953; Dinwoodie, 1960) have been carried out sampling internodally on a time scale according to Duff and Nolan (1953, 1957). Although the pattern of length variation is similar to that obtained previously, namely that there are three distinct patterns of variation within the tree that are merely different expressions of the same variation, the results are more reliable, the degree of variation in tracheid length being considerably reduced. In addition, the results appear to be more informative; thus Dinwoodie (1960) has recorded highly significant correlations between tracheid length of the first ring from the pith and the length of the internode, from which it may be concluded that the cell length in the first ring is closely related to the activity of the terminal meristem.

It can be argued on *a priori* grounds that sampling at fixed heights does not take into account the cyclic nature of growth. The most representative and practical sampling procedure for the comparison of trees would appear to consist of the removal of samples from the same percentage number of internodes from the base of the tree; failing this, sampling at the same percentage height is on the evidence available to be preferred to sampling at fixed heights.

A few investigations have been carried out to determine the relative length of the cells in the branches and roots compared with those in the trunk. It is generally agreed that the branch tracheids are shorter than the trunk tracheids (Sanio, 1872; Baranetzky, 1901; Hata, 1949; and Gleaton and Saydah, 1956); similarly the root tracheids and fibres have also been found to be shorter than those in the trunk (Fegel, 1941; Gleaton and Saydah, 1956), though Bailey and Faull (1934) record that the longest cells in a tree of *Sequoia sempervirens* occurred in the roots. Jackson and Green (1958*a*) record a correlation coefficient of 0·7313 for the stem/branch tracheid-length relationship in 39 slash pines.

The relationship between tracheid length and rate of growth

Considerable evidence is available regarding the relationship between cell length and the width of the ring as an index of rate of growth. Early work by Mork (1928), Chalk (1930), Helander (1933), Misra (1939), and Trendelenburg (1939) indicated that there was an inverse relationship between tracheid length and ring width, Chalk (1930) recording a correlation coefficient of $-0{\cdot}742 \pm 0{\cdot}005$ for *Picea sitchensis*. This relationship has been substantiated by Hata (1949) working on the pulping properties of *Pinus densiflora*; by Bisset, Dadswell, and Wardrop (1951) who studied various pine species; by Wardrop (1951); by the New Zealand Forest Research Institute (1953) which investigated some of the anatomical features of *Pinus radiata*; by Nylinder and Hagglund (1954) and Schultze-Dewitz (1959) for *Picea abies*; and by Elliott (1960) for *Picea sitchensis*.

This negative relationship has also been obtained by some investigators working with broad-leaved timber. Kuziel (1953) recorded such a relationship when investigating the difference in wood anatomy in four species of *Populus*; similarly Liese and Ammer (1958) for *Populus* × *robusta*.

Not all investigators, however, have recorded a negative relationship between cell length and rate of growth as expressed by ring width. Shepard and Bailey (1914) and Bailey and Shepard (1915) found no such relations in eccentric rings of *Pinus strobus* and *P. palustris*; Kramer (1958) also failed to establish any relationship for loblolly pine.

Both Gerry (1916) and Echols (1955) also reported no relationship between the length of tracheid and width of ring. Similar results have been recorded in storeyed hardwoods (Chalk, Marstrand, and Walsh, 1955) and this 'anomaly' has been related indirectly to the method of cambial division. A few investigators have recorded a positive relationship between tracheid length and rate of growth. Kennedy (1957) and Chech, Kennedy, and Smith (1960) in studying the effect of growth rate on cell length in *Populus trichocarpa* compared the length of tracheids in one-year-old stool shoots of unequal length. The results of this unique approach demonstrated that the more rapidly grown shoots possessed the longer tracheids.

Vasiljevic (1955) has recorded in *Picea abies* a positive relationship between length of tracheids and width of ring, while Susmel (1952) has also found such a relationship in *Pseudotsuga taxifolia*. Dinwoodie (1960) found a small positive correlation in the first eight rings of old Sitka spruce trees, whilst outward from this a high negative correlation was obtained; he related the positive correlation to parallel systematic increases outward from the pith of ring width and tracheid length.

Most of the early investigations of the effect of growth rate were carried out by comparing trees of different crown class or growing on different sites. Hartig (1898) concluded from an examination of five Norway spruce trees that tracheid length does not depend on the tree's individual growing capability and that it is possible to find both dominants and suppressed trees with long cells. Harlow (1927) also recorded negligible differences in tracheid length between two white cedar trees, one growing in a bog and the other on limestone, while Kienholz (1931) also found insignificant differences in three trees of *Pinus contorta* growing in a bog, in a virgin forest, and on a lava bed.

Mell (1910), however, found that the fastest growing of three trees on different sites had the longest tracheids. This positive relationship has been substantiated by Lee and Smith (1916), Kinnman (1923), MacMillan (1925), who found a decrease of 10 per cent. in the cell length in suppressed trees compared with dominants of *Picea rubra*, Neergaard (1928), Kienholz (1931), who compared trees of the same age but different heights, Helander (1933), Siriban (1939), Nilsson (1943), Cortes and Hambananda (1947), and Elliott (1960). Schultze-Dewitz (1959) recorded that the tracheid lengths of dominant Norway spruce trees were 3 per cent. greater than subdominants though the cell lengths of the latter were actually greater in early life. This positive relationship could be related to the results of Dinwoodie (1960) who found that tracheid length in the ring nearest the pith is highly correlated (positively) with the length of internode, an index of the rate of height growth.

In seedling material positive correlations between tracheid length and height growth have been recorded for *Pinus radiata* (Hartley, 1960) and *Picea sitchensis* (Dinwoodie, 1960; Dinwoodie and Richardson, 1961).

Scaramuzzi (1957*a*), however, in comparing the length of fibres in *Eucalyptus rostrata* growing on three different sites, concluded that the lengths of fibres were higher in the tree with the slowest growth rate.

It would appear, therefore, that once again considerable divergence of opinion exists as to any possible relationship between cell length and rate of growth. With regard to the width of the annual ring, the balance would appear to be in favour of a negative relationship with cell length, while, in the comparison of trees of different growth rates, considerable evidence is available indicative of a positive relationship between length and rate of growth.

The relationship between the increment of the cambium and the length of cells produced

It is unfortunate that the variation in the structure and activity of the cambium in forest trees with reference to the production of xylem cells has not received more attention. Most of the information that is available results from the detailed analyses carried out by Bailey (1920–3), Priestley (1930), and Bannan (1950–8).

Bailey (1920, 1923) made an intensive study of the cambium and deduced that the increase in perimeter in successive years was due to the addition of new initials arising by pseudotransverse division. Owing to the fact that neighbouring cambial cells did not elongate and divide in unison there was considerable variability in the length of neighbouring initials. Bailey further showed that the length of the last-formed tracheids bore a close relation to the length of the fusiform initials from which they were derived, generally being 5–10 per cent. longer. The length of the initials was shown to increase up to 200 years in some species.

Chattaway (1936), however, has shown that the mean fibre length in dicotyledonous woods may be 1·1 to 9·5 times greater than cambial initial lengths, though elongation to several times initial length only occurs when the initials are very short.

Priestley (1930) confirmed the presence of the anticlinal type of cambial division proposed by Bailey. He suggested that, if rapid growth is accompanied

by rapid transverse division of the cambium, the time lag before these new cells reached average length could lead to a shorter mean length of the fusiform initials. Wide rings, therefore, would be associated with relatively short tracheids, but unfortunately the cambium–xylem relationship has been shown to be much more complex than either Bailey or Priestley had envisaged.

The comprehensive contribution in this field by Bannan was prefaced by the published results of Whalley (1950), one of Bannan's assistants. Studies of serial tangential sections of secondary xylem in *Thuja occidentalis* were made. These indicated that the rate of division of the cambial cells was higher than that required to produce the necessary number of cells. Readjustment in the cambium was rapid, with extensive cell loss which appeared to be related to the length of the cell and to the number of ray contacts (Bannan and Bayly, 1956; Bannan, 1957*a*). The frequency of the divisions and the level of survival is a function of age (Bannan, 1960*b*), but is independent of rate of growth (Bannan, 1960*a*).

Bannan has indicated that the behaviour of the cambium is cyclic and in *Thuja occidentalis* the complete cycle of division, elongation, and initiation of division occurs in 4 years. Following division, 'the progress of elongation is not uniform, but rather follows a familiar growth pattern of early rapid extension, giving way to a gradually decreasing rate of elongation as lengthening proceeds' (1956). The presence of longer tracheids in the summerwood can be related to the fact that in this cycle of division and elongation, the pseudotransverse divisions generally occur towards the end of the growing season and elongation of the daughter initials is greater in the second half than in the first half of the following ring.

Chalk and Ortiz (1961) in tracing cell series across rings of *Pinus radiata* found that the pseudotransverse divisions of the cambial initials occur not only at the end of the growing season but also at the beginning of the next ring. They record appreciable intrusive growth in the summerwood tracheids and ascribe the decrease in cell length in the springwood to the pseudotransverse division of the xylem mother cells instead of the initials. Bannan (1957*c*), however, records that the proportion of extra-initial pseudotransverse division is exceedingly low, generally being about 2 per cent., though in one fast-grown specimen of *Cedrus deodora* the proportion of pseudotransverse divisions in the mother cells was as high as 20 per cent.

With regard to the relationship between ring width and tracheid length, Bannan's investigations have indicated that the circumstances which result in an increase in the rate of growth as indicated by a rise in the rate of periclinal division will encourage earlier pseudotransverse division and the production of shorter tracheids; the earlier the fusiform initials are transversely divided in their cycle of elongation and division, the shorter will be the mean length of the derived tracheids (1954, 1957*a*). In a later paper, however, Bannan, whilst substantiating the presence of the inverse relationship between cell length and ring width, has shown rather surprisingly that the frequency of the pseudotransverse division which one would expect on previous results to affect tracheid length is not obviously related to growth rate as expressed by cell number but rather to

the linear radial increment (1960*a*). Chalk and Ortiz (1961) again suggest that the decrease in cell length in wide rings is due to an increase in the number of pseudo-transverse divisions of the xylem mother cells.

The investigations of Chalk, Marstrand, and Walsh (1955) on storeyed hardwoods have indirectly yielded some valuable information on cambial activity in non-storeyed timbers. Thus in trees with a storeyed cambium, in which the cambium does not divide anticlinally, there is no progressive increase in fibre length outward from the pith. Moreover the 'absence of any relation between ring width and fibre length in storeyed woods, supports the view that in non-storeyed woods the negative correlation that has been observed is due to the method of cambial division'. However, Hejnowicz and Hejnowicz (1959) have recorded a progressive increase outwards in the length of the latewood fibres in *Robinia pseudoacacia*.

Priestley (1930) releated the increase in tracheid length in successive rings to increasing radial pressure in the expanding stem. However, Wardrop (1948) and Bannan (1957*b*), in studies on stems subjected to pressure and on eccentric stems respectively, did not consider such radial pressure to be responsible for the progressive increase in tracheid length. Shimaji (1950) from an examination of four dicotyledonous species has suggested that the tension on the cambium may be the limiting factor for at least part of the tree's life.

Liang (1948) found a highly significant relationship between the length of tracheids and the percentage perimeter increment of the cambium, expressed by the ratio $R2/R1$ ($R2$ represented the radial distance to the ouside boundary of the two rings being sampled, and $R1$ the distance to the inner boundary). Marstrand (1954) also found a negative correlation between length and increase in unit girth of the cambium, expressed this time by the ratio $\frac{R2-R1}{R2+R1}$. He applied this ratio to Liang's figures and also to those published by Bisset, Dadswell, and Wardrop (1951).

Genotypic and ecotypic variations in tracheid length

Considerable evidence is available in the literature regarding the variation in tracheid length in different species of the same genus. Both Brown and Panshin (1940) and the F.P.L., Madison (1953) provide average tracheid lengths for different species.

Kuziel (1953) noted in a study of four species of *Populus* that length varied with species, while Meyer-Uhlenried (1959) noted that, in the same genus, length was significantly different between the two sub-genera, but not within them.

It would appear, therefore, that considerable variation in cell length may occur between species in any one genus. It is possible, therefore, that variation within a species is also related to differences in genotype. However, little information is available regarding the variation in tracheid length within a species in the comparison of individuals, races, provenances, or forms. This deficiency may be due, in part, to the variation in length within the tree; the wide range in cell length has made it extremely difficult to obtain a standard for comparative purposes.

Most of the investigations in this field have suggested the possibility of genetical control, but in many cases this has been ascribed to inexplicable variations in studies between trees. Echols (1955) suggested the possibility of genetical control in *Pinus caribaea*, while Morris (1948) and Schreiner (1958) indicated the possibilities of breeding for strains of tree species with relatively long cells.

A difference between trees, in the pattern of tracheid-length variation with age, has been demonstrated by Liang (1948), Dadswell (1957), and Dadswell and Nicholls (1959). In the last paper, a considerable proportion of the variation in tracheid length between the strains could be accounted for by variation within the trees. Since systematic variation up the tree has been recorded (see previous sections) removal of samples at the same fixed height from trees of different heights will provide erroneous average tracheid lengths for comparative purposes.

Examinations of the possibility of genetical variation in length have been made by Kennedy and Wilson (1954) who concluded that the smooth-bark form of *Abies lasiocarpa* has significantly longer tracheids than the cork-bark form. Variation in tracheid length within different forms of *Picea abies* has been demonstrated in an intensive study by Nylinder and Hagglund (1954). They record the longest tracheids in the 'broom' form and the shortest in the 'band' form. In comparing the length of tracheids with the latitude of origin, a partial positive relationship was obtained.

Susmel (1951), in comparing the anatomical features of Norway spruce timber growing in Sweden and in the alpine region, concluded that the mean length of the tracheids was much greater in trees in the alpine forests than in those growing in Sweden.

Jackson and Green (1958*b*) carried out a series of cross-pollination experiments in both *Pinus caribaea* and *P. taeda*. In five out of a possible seven combinations the tracheid length of the progeny was intermediate between that of the two parents; they conclude from this that it would be possible to breed for long or short tracheids.

Hartley (1960), in the study of the effects of nutrients on tracheid length of *Pinus radiata* seedlings, has attributed the differences in length between the seedlings to genetical control as a result of open pollination.

Bisset, Dadswell, and Wardrop (1951) compared four different strains of *Pinus pinaster* (Leira, Corsican, Landes, Esterel), sampling the first, second, and twelfth rings in five trees from each of the four strains. The Esterel strain appeared to have the longest tracheid length and Corsican the smallest, with Landes and Leira intermediate and similar. However, once again, the samples were removed at a fixed height in the tree and, in addition, the intensity of sampling is low for comparative purposes. Differences in tracheid length in the initial ring could be due to differences in the length of the internodes in the four strains.

An intensive investigation on the effect of provenance on tracheid length was carried out by Echols (1958) on *Pinus sylvestris*. Unfortunately, the significance of the results of this study is lowered owing to the fact that in comparing fifteen trees, from each of fifteen different races, no attempt was made to eliminate or reduce the effect of variations in height and diameter growth between the races.

Samples were removed at a height of 4·5 feet in thirteen races and at 1 foot in the remaining two races and, as the trees ranged in height from 7·3 to 24·3 feet, sampling, therefore, was carried out over a range of percentage heights from 10·4 to 43·0 feet. Thus it would be expected that, as length decreases up the tree, lower tracheids would be obtained with increasing latitude, owing to the removal of samples at relatively higher levels in the smaller trees from the northern latitudes. It is possible, therefore, that a considerable amount of the decrease in tracheid length with increasing latitude can be accounted for by differential growth rates. Differences in ring width between the races were also ignored.

Dinwoodie (1960) in an intensive investigation on *Picea sitchensis* indicated the possibility of ecotypic variation in tracheid length. This was the outcome of studies on tracheid-length variation outward from the pith (on both age and distance from the pith basis) in sixteen blocks of timber removed from 10 per cent. the height of 120–360-year-old trees from eight different latitudes in North America; of investigations of the same variation on 11 mm. increment cores removed from 10 per cent. the height of six 28-year-old trees from each of four provenances growing in this country; and by statistical comparison of the tracheid lengths, corrected for height growth, of twelve one-year-old seedlings from each of twelve provenances.

In the timber from North California the average cell length was about 50 per cent. greater than in rings of the same width and age in timber from Alaska. In the outer rings (25–30) of the home-grown timber, the Californian tracheid lengths were 12 per cent. greater than those of Queen Charlotte Islands. In an experiment to determine the effect of photoperiod on tracheid length, the seedlings from North Bend (Oregon) were greater by 20–27 per cent. than seedlings of the same height from Juneau (Alaska) (Dinwoodie and Richardson, 1961).

In concluding, it would appear that there is variation in cell length with latitude of origin, cell length decreasing with increasing latitude, but in the light of individual tree variation it is relatively small. Thus the variation in cell length within the ring (5–30 per cent.) and the variation outward from the pith (200–500 per cent.; Dinwoodie, 1960) are as great or greater than the recorded ecotypic variation.

If provenance does have an effect on cell length, then it is difficult to understand how length *per se* has been naturally selected; it is more likely that length is associated with some other factor or factors that have been naturally selected. Richardson and Dinwoodie (1960) and Dinwoodie and Richardson (1961) have shown that tracheid length is a function of temperature and it is possible that latitudinal differences in tracheid length result from genetically controlled adaptation to topoclinal differences in temperature during the growing season. Much more research is required in this field.

General conclusions

It will be observed from this review of the literature that, in some aspects of tracheid-length variation, little previous work has been recorded, while in others

a considerable number of investigations have been carried out, the results of which are often contradictory.

The presence of conflicting findings is particularly prevalent in the studies of tracheid-length variation outward from the pith at any one height in the tree. Less contradiction is found, however, in investigations of length variation within the growth ring and in a vertical plane within the tree.

In the relationship of tracheid length to such factors as age, rate of growth, and distance from the pith, most of the investigations have once again yielded conflicting results.

At the present time there is a distinct lack of information on the genotypic variation in tracheid length, particularly on the mechanism of this variation.

Perhaps the most important aspects that require attention are the exact role of the terminal meristem in determining cell length and the relationship between this meristem and the cambium.

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CROWN DIE-BACK AND DEBILITY IN CORSICAN PINE (*P. NIGRA* VAR. *CALABRICA*) IN BRITAIN

W. R. DAY

(With four plates)

SUMMARY

This paper is concerned with disease in the crown of Corsican pine (*P. nigra* var. *calabrica* (Loudon) Schneider) in plantations in Britain. Two main aspects of disease are discussed; in one a dying back of terminal shoots is seen; in the other a loss of crown condition develops. The dying back is regarded as based on injury either by low temperature or deficiency in water supply; it occurs characteristically in stands in the thicket stage. Loss of crown condition is seen mainly in poor leaf equipment and is regarded as based on various aspects of soil condition, of which physical conditions for root development and action are regarded as being the more important. Infections and infestations occur, but in so far as they directly concern shoot dying back are regarded as of secondary importance; though in the presence of large populations, beetle infestations may be of primary importance. There are suggestions that infections of the smaller roots are sometimes of appreciable importance as causes of loss of crown condition through reducing the availability of supply from the soil.

INTRODUCTION

THERE are two main types of disease, or debility, which in Britain affect the crown of Corsican pine. One is signalized by a dying back of terminal shoots and in its most common acute form is associated characteristically with even-aged stands which are in the thicket stage of development; in the other there is typically a loss of foliage density which at first affects the lower part of the crown, but in its more severe forms may affect the whole. This loss of foliage density is associated with the formation of a high canopy. Both types may be seen in one tree, although equally both may be seen separately; or alternatively a stand may first show terminal die-back and later loss of foliage density. It is with the resolution of certain aspects of this complex that this paper is concerned: in order to make clearer the scope of the discussion, an analysis is given of the more common aspects in which the two general types of disease show themselves.

A. *The terminal buds die; or leading shoots die back; or the top of the tree may die to a greater or lesser extent*

1. *Die-back owing to water-shortage.* The observed cases were trees of between about 6 and 15 feet in height. The whole top of the tree died: small patches in which the bark had died to the cambium occurred on the main stem below and particularly in nodal regions.

The sites were obviously drought-susceptible and death of tissues took place at about the time of change-over to late wood production (Photos. 1 and 2); that is probably some time in July. Bark-beetle infestation of the dying parts usually follows this type of injury and may take place in the still living lower part of the main stem, thus causing the death of the whole tree. The number of trees concerned in observed cases has been small and the effect of their loss on the later

stages of the stand not very obvious. A recent and serious occurrence of dying back of Black pine determined by drought has, however, been described in Austria (Donaubauer, 1960).

2. *Die-back associated with lime-induced chlorosis.* Corsican pine may grow successfully to a considerable size on calcareous soils: this may be seen, for example, in many places on the Cotswold Hills. Sites occur, however, on which it suffers from lime-induced nutrient deficiency: other species of trees, e.g. the larches and beech, tend also to be susceptible in such places. The deficiency seems usually to have been imputed from the general appearance of the tree; but experimental proof of iron deficiency has been obtained a number of times for beech on such sites. Scots pine suffer at least equally. Affected trees grow poorly and show a dying back of shoots which is often accentuated by infestation with *Myelophilus piniperda*, the larger pine-shoot beetle. There are indications in Allerston Forest that this condition is a phase which some trees survive so that an open stand develops, in this case with an understorey of beech planted to fill in gaps. Stands on soils derived from both chalk and the harder limestones may be affected; the trouble is usually strictly local.

3. *Die-back associated with infestation of shoots by* M. piniperda. This may take place to a serious extent quite independently of any predisposing factor if a sufficient population of beetles develops: populations may breed in trees dying from other causes and in this way infestation of shoots or stems may become a secondary factor of some importance. Means of control of beetle populations are well known and ordinarily their development should not occur.

4. *Death of terminal buds and shoots usually associated with infection by* Scleroderris abietina (*Lgbg.*) *Gremmen* (= Crumenula abietina *Lgbg.*). This is the form of dying back which is most commonly recognized and usually has been associated with the pycnidial form of the fungus, *Brunchorstia pinea* (Karst.) von Höhn. (= *B. destruens* Eriks.). The observed condition may be the result of a complex in which one or more of the four factors of frost injury, water shortage, nutrient deficiency, or insect infestation have also had effect, and herein lies one source of difficulties in diagnosis. This is the aspect of terminal dying back principally discussed below.

B. *The crown develops a low foliage density*

Healthy, vigorous, Corsican pine grown in a closed stand develop densely foliated crowns, the depth of which depends largely on the growing-space available. Foliage density and growth vigour decreases as the crown is descended, but under ordinary observation change in density is not very noticeable and at the base of the live crown there is a quick changeover to bare branches killed by suppression. A stand in which the trees possess such crowns keeps all ground vegetation suppressed and may keep an entirely clean floor at least until the trees are 70 to 80 feet in height. This condition is not uncommon in the better stands in the southern part of England. Often, however, a much lighter canopy exists so that a more or less vigorous understorey develops. A considerable variety of factors probably acts to produce this lighter condition of canopy. There has

never been any full investigation of the matter and only some of the more obvious conditions, or those which appear to be relevant to this discussion, can be mentioned. It is assumed that exposure to wind blast and other directly defoliating agents are of no appreciable significance.

1. *The dominated trees show low foliage density.* This is a normal result of competition in a healthily developing stand and needs no further consideration.

2. *Low foliage density appears in the codominants and dominants, the latter tending to retain most vigour.* This is a condition of very general occurrence in varying degrees. It may show as soon as a stand leaves the thicket stage, but often it does not appear until much later.

(*a*) *An insufficiency of water, or nutrients, or both, prevents the continued maintenance of a full canopy density.* The less effective competitors accordingly lose in foliage density, or crown size, when the limiting condition of supply is reached. This is a common condition in native Black pine forests, as, for example, in Cyprus. It is then a stage in the development of open forest under conditions in which soil supply, considering the climate prevailing, is inadequate to maintain a full stand as the trees grow larger. Bark-beetle infestation and phloem necrosis (Day, 1960) may appear at appropriate stages and, since sites of low supply tend often to be deficient in nutrients, symptoms of nutrient deficiency may be discovered. The basic adverse factors are to be found, however, in an unduly low general supply of food and water from the soil. Another factor of importance is the competition of understoreys for rooting space and, in Britain especially perhaps, of a ground cover of herbs, grasses, and small shrubs, such as becomes established naturally once a light, open, canopy has developed.

(*b*) *Root infections develop.* It is probably never possible to separate this condition absolutely from the former; but it may be considered separately. Usually the early growth of the stand, for perhaps the first three or four decades, is satisfactory. It may then be observed that trees isolated in thinning remain, or become, of low foliage density, or that the depth of dense crown diminishes rather than increases. In many cases at least this condition seems to be determined by root infections, sometimes by fungi such as *Armillaria mellea* or *Fomes annosus*; but probably more often than is thought also by infections of the smaller roots such as may be caused by *Pythium* and *Phytophthora* spp. Root infections in the U.S.A. (Campbell and Copeland, 1954) and New Zealand (Newhook, 1959; Sutherland *et al.*, 1959) provide examples of this on other species of pine. Adverse conditions as predetermining debility and predisposing to infection probably always operate. An example may be given from Bagley Wood, Oxford, from a site on which the soil is derived from a gravel which overlies Kimmeridge clay. In times of severe drought roots die from water shortage; during periods of soil saturation anaerobic conditions may develop temporarily in part of the space rooted and particularly in zones of impeded drainage; both *A. mellea* and *F. annosus* occur as root infections. These conditions have not caused untimely death of trees in a stand subject to silvicultural thinning; but they affect crown development. It is known from examination of wind-throws that there is a general tendency to root disease on this site, and a sensitive species, such as is Sitka spruce

(*Picea sitchensis* (Bong.) Carr.) in this locality, shows this markedly at the age of 55 years by its very poor crown condition and the slow dying of trees.

3. *Other factors.* The above two general conditions, namely inadequacy of supply from the space rooted and the development of root infections, seem to provide the main sources of importance for the development of an unduly low foliage density in individual crowns and particularly those of dominants and codominants. Exposure to strong winds may be of regional importance and particularly in places directly exposed to strong sea winds (Brown, 1957); but this does not come into the cases considered below. Infection by needle cast fungi such as *Hypodermella sulcigena* (Rostr.) Tub. has also been of local importance; but again this does not seem to have been of any great significance in the regions under observation. The same is probably true for needle die-back; in this the major distal portion of the needle dies, leaving the basal part alive. It seems to occur more severely on the type of pine with long flexible needles, considered to be the true Corsican variety of Black pine, than on the more green and stiffer-needled types which sometimes occur commonly. A variety of fungi are associated with this needle scorching (Day, 1945; Peace, 1953) but it seems to be probable that low temperatures often associated with cold winds are the real cause of trouble. It is possible locally that defoliation in this manner has been an important factor in the development of debility; but there has been no clear proof of this.

THE DYING BACK OF TERMINAL BUDS AND SHOOTS: ITS CHARACTERISTICS AND CAUSE

This disease, which as stated above is usually associated with infection by *S. abietina*, has been observed on a number of species of pine (Ettlinger, 1945; van Vloten and Gremmen, 1953). It has been observed by the writer in Britain on Corsican pine, Austrian pine (*P. nigra* var. *Austriaca*, Aschs. and Gr.), Scots pine (*P. sylvestris* L.), Mountain pine (*P. montana* Mill.), and Maritime pine (*P. pinaster* Sol.). Any descriptions or remarks made here apply to Corsican pine; its occurrence on other species of pine has not been specially investigated. Other fungi than *S. abietina* have been recorded as occurring on affected trees, e.g. *Crumenula pinicola* (Fr.) Karst., *Cr. sororia* Karst., *Cenangium ferruginosum* Fr. (= *C. abietis* Duby.), and *Dasyscypha calyciformis* (Willd.) Rehm.: but these have usually been regarded as only weak parasites or saprophytes.

This disease was common in a number of localities in England during the early 1940's and mostly in plantations which were in, or about to enter, the thicket stage. It was then investigated by the writer, who came to the conclusion, partly on field but partly on anatomical evidence, that injury by early and late frost was the main cause of trouble (Day, 1945): there is no doubt, however, that water shortage is also a basic determining factor (Donaubauer, 1960). There were reports of similar disease from Holland (Voorbeytel Cannenburg, 1942) and in Belgium (Boudru, 1947) at about this time; in these cases also young stands were characteristically affected. Experience during the last fifteen years has shown that in certain localities, for example on the moors and particularly in the dales in

Allerston Forest in eastern Yorkshire and on the fells in Slaley Forest, Northumberland, the disease has persisted and locally, as in parts of the Staindale Section of Allerston Forest, has been catastrophic. Fresh outbreaks have occurred in suitable situations; e.g. on high-lying moorland sites in the Kerry Hills, Shropshire, and in western Monmouthshire. Because of these things it seemed to be desirable to go into this matter again, and this paper is based mainly on the results of this re-examination.

SYMPTOMS OF THE DISEASE[1]

1. If an affected stand, such as has occurred in the north of England, is examined when the disease is in an early stage and during the first part of May, when buds have begun to elongate, it will be noticed (*a*) that some of the terminal buds have failed to elongate; (*b*) that some terminal shoots bear pale, rather dry-looking, yellow-green needles on the distal part, the needles at the base of the shoot being normally green. Further, (*c*) the discoloured needles show brown bases, this coloration extending up the needle for about $\frac{1}{8}$ inch. (*d*) Patches of browned, dead tissue may occur on the lower live part of the shoot: they also often occur on older shoots. Some of the larger of these injuries may appear as small cankers which ordinarily have the appearance of having started to heal over.

2. If now shoots are split down with a sharp knife it will be seen that some of the dead terminal buds are dry and brown and have been dead for some time; but that others are wet with resin although still brown. The resin appears most abundant at the base of the minute shoot which the bud encloses (Fig. 1). Yet other unshot buds may be found, the upper part of the shoot within which is still green and living, while the lower part is brown, dead, and wet with resin; plainly these are cases of quite recent injury in which the base of the developing shoot, that is the point at which extension growth starts in spring, has been killed. If still further search is made, cases may be found in which the terminal buds are entirely green and undamaged but have not shot: part of the shoot below the bud will be found to have been killed and girdled, and to be a wet dark brown in colour; or sometimes a remnant of normal colour may be found. The girdling of the shoot in these latter cases thus prevents the development of the terminal buds above. Quite freshly injured shoots such as these may bear fresh green needles arising from the brown, dead bark; but if examination is made of shoots the ends of which bear needles discoloured pale green, the bark of the shoot beneath them will be found dead and dry. The indications are thus that the bark of the shoot is killed first and that the needles attached dry out subsequently, becoming brown at the base and eventually, of course, wholly brown. Commonly, a shoot which bears discoloured needles for any large part of its length shows a dark, resin-soaked zone at the base of the dead part (Fig. 1), indicating that it died owing to being girdled by injury at this point.

3. On proceeding down the shoot below the entirely dead part, or below the newly girdled part if a quite freshly injured shoot is examined, it is usual to find,

[1] Recent experimental freezing has demonstrated that the main features described below can arise through injury by low temperatures.

more or less commonly, small injured patches: sometimes these patches are situated at the bases of dwarf shoots. If the injury is quite fresh the patch, on being cut through, will be wet with resin and may vary in colour from a sodden pale yellow to dark brown. The needles of a dwarf shoot based on such a patch

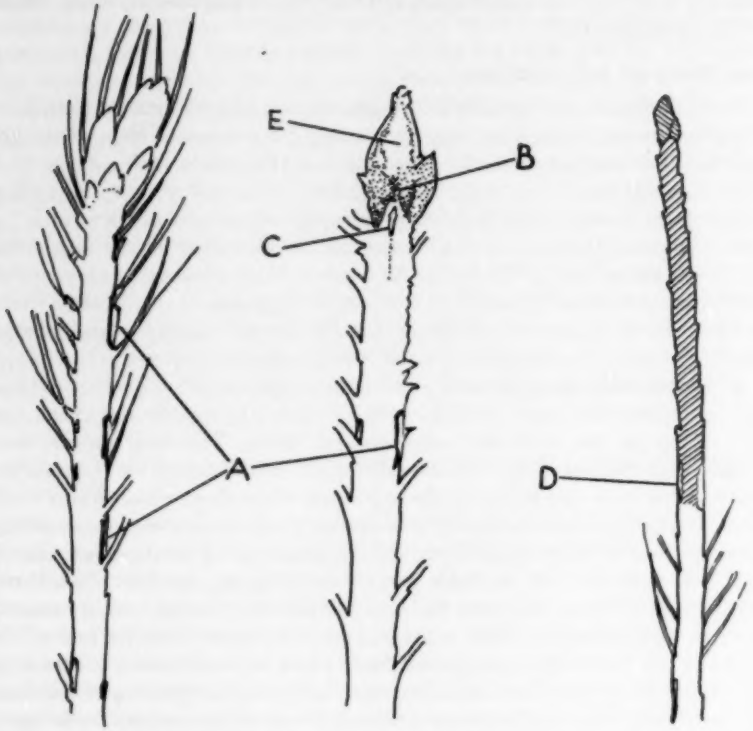


FIG. 1. Diagrammatic representation of injuries to Corsican pine shoots. The left-hand shoot shows only patch injury in the bark (A): the middle shoot, a newly killed terminal bud with a dead base (B) but a still green upper part (E); the medulla is injured at C. The right-hand shoot was girdled at (D) by a severe patch injury.

are at first normally fresh and green in colour, and it is plain that, in this stage, the injuries have occurred only recently. Farther down the branch older injured patches may be found: usually these have not penetrated to the cambium and are cut off by a cork layer. Extension of injury seems usually not to take place, though it may occur; and when it does so a small open wound or canker is found. There is thus some, though usually slight, tendency to canker formation on affected trees.

4. If sections of damaged shoots are examined the following will be noticed:

A. Dead shoots in transverse section show completely shattered tissue (Photo. 3);

not uncommonly also small rents, indicative of tangential collapse of tissue, are found in the meristematic zone. Sometimes, at least, the presence of the first newly developed, unlignified, wood cells indicates that death took place around the time of onset of meristematic activity in spring. Examination shows that Corsican pine begins cambial growth first, and ends it latest, in its terminal shoots. Thus at Oxford, in 1959, such growth of terminal shoots had already begun by 5 May, several rows of wood cells having been formed, and was still not finished by the middle of October; although on older stems, at both dates, the cambium was dormant. The observation of Freni (1956) that in Calabria the turgescence which precedes cambial activity in Black pine occurs in mid-April suggests the possibility of susceptibility to frost injury in such climates as that of Great Britain. On the other hand there has been no proof so far that injury by winter frost, such as has been reported from Belgium, occurs here (Naets, 1955; Boudru, 1947).

B. This shattering of tissue is also typical of the patch injuries described above and it is to be taken that the cause of shoot die-back and of patch injury is the same. Newly killed patches may be found in suitable situations, from at least the latter half of April. Even as late as the middle of June these latest injuries may still be wet with resin; though before the growing season is out they will have dried and cork layers will have formed to isolate them from adjacent relatively little injured tissue.

C. It is also a common characteristic that the medulla is injured in the vicinity of patch injury: the injured medulla appears as brown in colour. The parts of shoots which are killed show a more or less severely rent and collapsed medulla, the parenchyma of the primary rays commonly being the most seriously affected (Photo. 4). A shoot, the bark of which has been damaged seriously on one side only, shows the most serious injury to the medulla on that side. Sometimes the medulla on that side is killed, but not on the other and less seriously injured. The killed part may be merely isolated by a cork layer; but sometimes a meristem forms which develops vascular tissue so that locally a stem tends to form within a stem. If a seriously damaged shoot is split longitudinally in the field the rents in the medulla can commonly be seen by eye unaided.

D. Evidence as to date of death of cambium in injured shoots may be found by examination of transverse sections. Injury almost always takes place after shoot growth in length and bud development has been completed and before there is any obvious new growth in spring. Corsican pine sometimes forms lammas shoots and field observation has suggested that these are sometimes killed at the end of the growing season. There is usually, however, as much as 6 weeks or 2 months between the cessation of shoot growth in length and the cessation of growth in diameter in the most recently formed shoots. Sections of injured shoots have shown:

(i) Collapse in the meristematic zone during the period of late wood formation, in shoots which have died owing to drought (Photos. 1 and 2). This is a summer phenomenon and probably can take place as early as July, and in this way it differs from the type of injury described in detail above. Anatomically the injury occurs in various forms and degrees, and the development of collapse pipes may take place

only locally within the area of bark affected. This type of injury has been observed in material from widely separated regions, e.g. South Wales. Cornwall, Lake District, Eastern Yorkshire, and must be accounted as occurring commonly during appropriate years. Death of cortical and phloem tissue commonly takes place as an aspect of drought injury, and collapse in the medulla also commonly occurs.

(ii) The formation of late summer, or early autumn, frost rings in association with local death of cambium. The best examples of this were found in Slaley Forest in 1944, but it has been observed in material from a number of places. The frost ring occurred as a zone diving two annual rings (Photo. 5). It is difficult exactly to date such an occurrence; but the great probability is that injury occurred in late summer.

(iii) Sometimes spring frost rings are to be seen in association with adjacent death of cambium (Photo. 6). Death of cortical and often of phloem tissue also commonly takes place under conditions in which frost rings form. On the other hand it is unusual to find examples of shoots killed in process of elongation, i.e. approximately during May and early June. Damage to protoxylem tissue sometimes occurs, however (c, Photo. 4), and this must have taken place during shoot elongation.

(iv) Two- or three-year-old shoots often show dead outer bark, particularly in the vicinity of nodes: death may take place as deeply as the phloem and sometimes the cambium is killed. Resin flow is often seen and sometimes to a copious extent. The wood of shoots so affected commonly shows abnormal ring endings: instead of the normal one or two outer rows of narrow, coffin-shaped cells, as many as six or eight, or occasionally more, may occur (Photos. 1 and 7). Sometimes, also, the ring boundary is formed by a zone of parenchyma (Photo. 8). A deep zone of narrow cells is plainly a case of arrested development; this may take place as early as July and in association with dry conditions: as in the case of Photos. 1 and 7, it may occur in stems the apex of which has died owing to drought. It is suggested thus that this is an aspect of injury by water shortage, mentioned under (i) above. Bounding narrow zones of parenchyma may arise similarly: but Day and Peace (1934) showed that it is possible to injure a cambium by low temperature at the end of the growing season, and for the abnormal tissue which results to appear at the beginning of the next annual ring. Photo. 5 shows that this can happen in the case of frost injury at the end of the growing season. More investigation of this matter is needed.

(v) It has been pointed out above that the bark of terminal shoots killed shows collapse and rending of tissues, and that sometimes, at least, this takes place at a time when the first new but still unlignified xylem cells have formed: this is plainly a spring occurrence, timed for the renewal of cambial activity.

5. The above statements suggest that terminal dying back of Corsican pine takes place owing to the action of physical factors during the growing season and that both low temperature and water deficiency may be effective causes. The microfloral ecology of the disease has not been studied; but is quite easy to show that injured parts are colonized quite early by mycelia and that one of these is

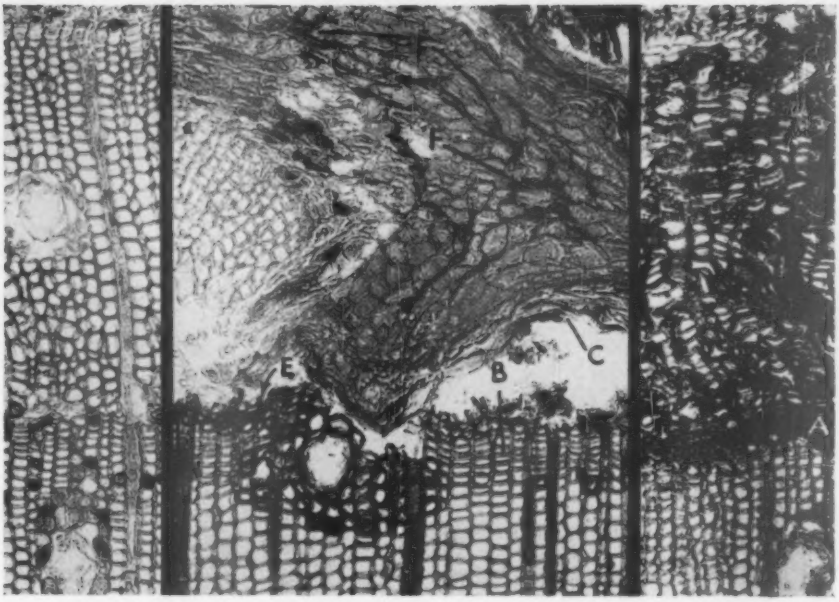


PHOTO. 1. A, death of meristematic zone in summer, in centre of injury; with B, arrested development in tracheid size, on edge of injury, and below the tissue within which the cork layer C formed. Tracheid proportions are still abnormal below D and on the same growth horizon. D, parenchyma zone at beginning of next annual ring and the consequence of a further slight injury at E. F, the dark areas are collapsed phloem tissue embedded in secondary cortex. Rheola Forest, Glamorgan. Magnification, × 116.

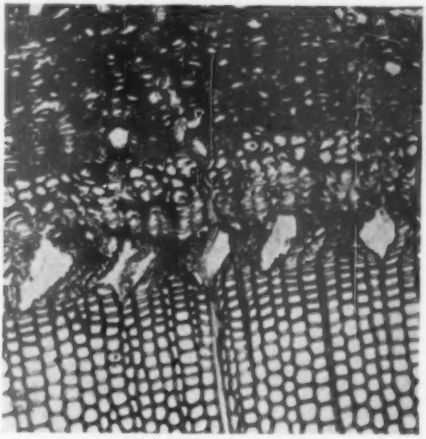


PHOTO. 2. Collapse across the meristematic zone, with tangential shrinkage and rending of tissue. This took place shortly after onset of late wood formation. Part of a section cut near to the base of a dead top of a Corsican pine. Rheola Forest, Glamorgan. Magnification, × 95.

PLATE VIII

PHOTO. 3. Transverse section of part of a terminal shoot killed when the first new xylem cells had formed but were unlignified. The tissues of cortex, phloem, and medulla were completely shattered and collapsed. Allerston Forest, Yorkshire. Magnification, × 43.

PLATE IX

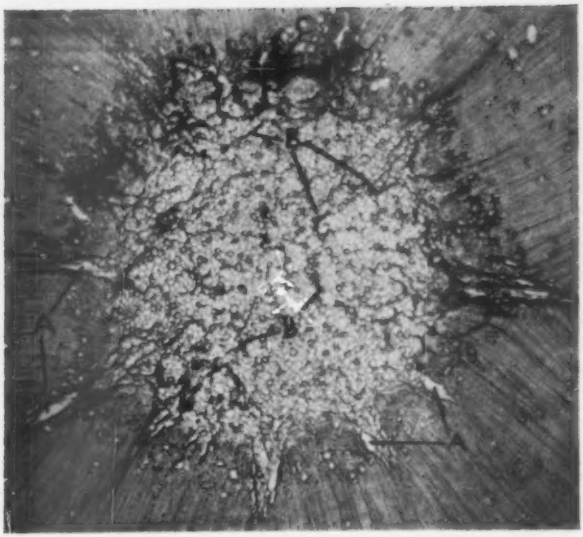


PHOTO. 4. An injured medulla from a 4-year-old main stem of Corsican pine, the top of which had died owing to drought. Note the collapsed and rent primary ray tissue (A) and the dark lines (B) indicative of local collapse in the medulla. Injury in spring to the developing terminal shoot occurred at (C); this is considered to have been caused by frost. Rheola Forest, Glamorgan. Magnification, × 10.

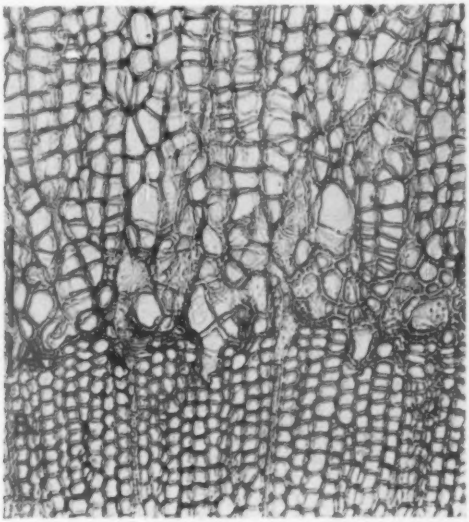
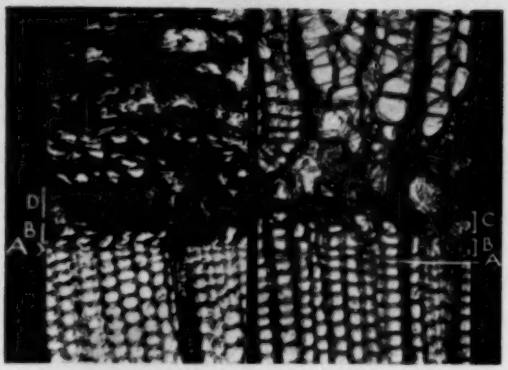


PHOTO. 5. An abnormal zone of tissue in a young main stem of a Corsican pine which showed terminal dying back and canker. This is considered to have formed as a reaction to injury by early frost. Note that the reaction tissue developed in the year following the occurrence of injury. A, zone of collapse; B, late wood; C, reaction zone in early wood of year following injury. Slaley Forest, Northumberland. Magnification, × 116.

PLATE X



(1) (2)

PHOTO. 6. From a 3-year-old dead main stem of Corsican pine. (1) The dead inner bark with first new xylem elements inside it (B). (2) A spring frost ring in the wood of the previous year; this occurred at about the same date, in terms of ring development, as death in (1). A, end of annual ring; B, first new tracheids; C, zone of radial collapse at base of frost ring; D, collapsed dead meristem. Delamare Forest, Cheshire. Magnification, × 107.

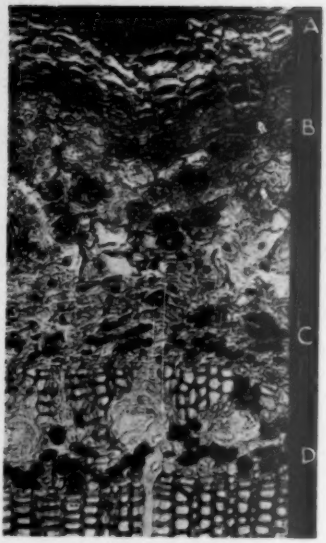


PHOTO 8. Abnormal ring ending. A, cork layer isolating dead phloem tissue; B, secondary cortex developed from phloem parenchyma; C, phloem; D, parenchyma zone between two annual rings, with traumatic resin ducts following. Haldon Forest, S. Devon. Magnification, × 104.

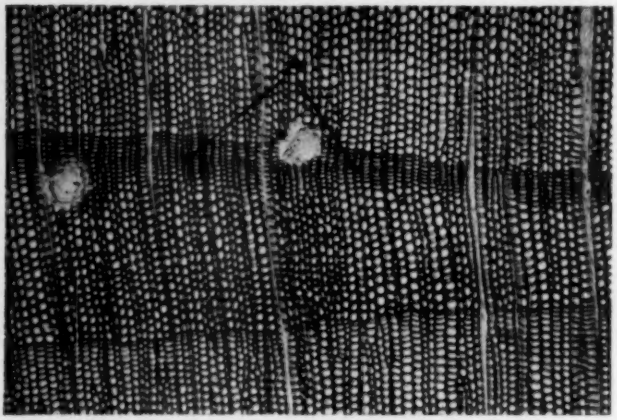


PHOTO. 7. A transverse section from the main stem of a young Corsican pine. The complete annual ring is for the year 1942. It is narrow after severe drought injury to the tree in 1941 and itself shows the effect of drought in arrested development in radial growth shown in the late wood (A). Rheola Forest, Glamorganshire. Magnification × 46.

PLATE XI

often *S. abietina*. Other species of fungus may occur more abundantly, however, and not only in the dead tissue but also in the partly injured tissue which surrounds dead areas. There seems to be no obvious reason why such mycelia may not exert some parasitic action; but it is difficult to find anatomical evidence that this is ever of great importance as an initial cause of disease. Discussion of this problem often is made more difficult by the subsequent development of disease. Some aspects of this are discussed below.

THE DEVELOPMENT OF DISEASE AS STANDS BECOME OLDER

1. It has already been stated that disease, as a dying back of terminal shoots, is particularly, though not necessarily, associated with the development of the stand into a thicket stage: e.g. in the early stages of disease in Slaley Forest, the more slowly growing and, in 1944, still open parts of the plantations were not much affected; but patches of seriously diseased trees occurred in the better-grown parts in which alone a closed thicket of crowns had developed: this has been observed in a number of places. Counting the number of internodes on trees which were the first to die in affected stands also provides evidence that this is true. The better growth takes place on the more fertile sites and often these are in the more low-lying, water-receiving, places in which the deeper soils tend to occur: such situations naturally hold cold air and so are more subject to low temperatures (Day and Peace, 1946). Examples of such sites are the base of the slope and the valley bottom in Dickson's Slack, a narrow, ravine-like valley in Staindale Forest; the gentle hollow in which Swair Dale, in the same forest, fades out into the moorland plateau; the bottom of a narrow valley in Harwood Dale Forest; and the lower slope of a small valley in the Whickhope section of Kielder Forest. Sitka spruce, as a small tree, shows marked frost pruning in such places, though once above the dangerous zone it may grow well and tend to suppress a pine.

2. When the disease is not so critically serious the tendency is for smaller or larger patches in the stand to grow up into a high canopy and form relatively healthy crowns: e.g. on the plateau sites in all the older parts of Allerston Forest, as well as in Slaley Forest, a mosaic has developed in which some patches contain seriously decrepit or dead trees, and other trees the crowns of which are relatively satisfactory and passing into high canopy. If stands are examined which have been injured and are developing after this fashion, a number of things may be observed. Firstly, the reaction to killing of terminal shoots is to produce adventitious shoots from dwarf shoots situated below the base of the parts killed. The number of these seems to depend on degree of injury to, and on residual vigour of, the tree. It would appear to be normal for many of such adventitious shoots to die, even when some successfully form new branches. The common case in the areas examined has been, however, that all adventitious shoots die within one or two years of their formation and it is possible through this for a severely affected tree to produce few, or no, new needles. The old needles lose in colour and condition and it would seem that trees which remain stagnant in this way die. The observations of Georgescu and Catrina (1957) on movement of water in Black pine

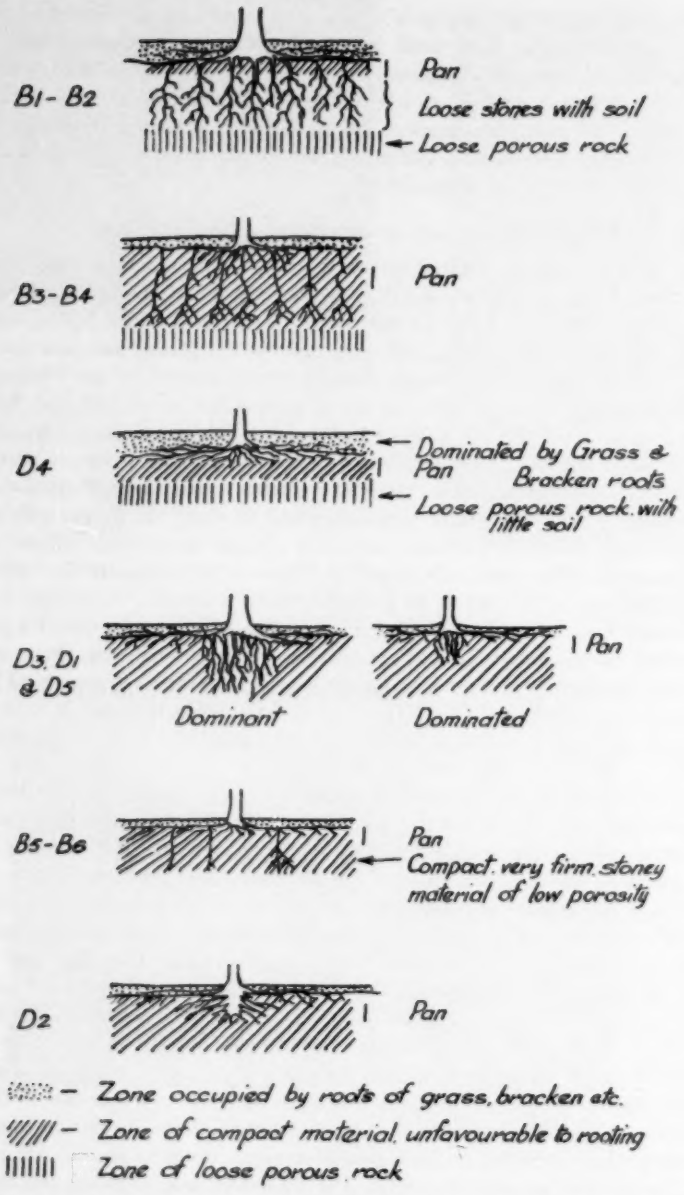
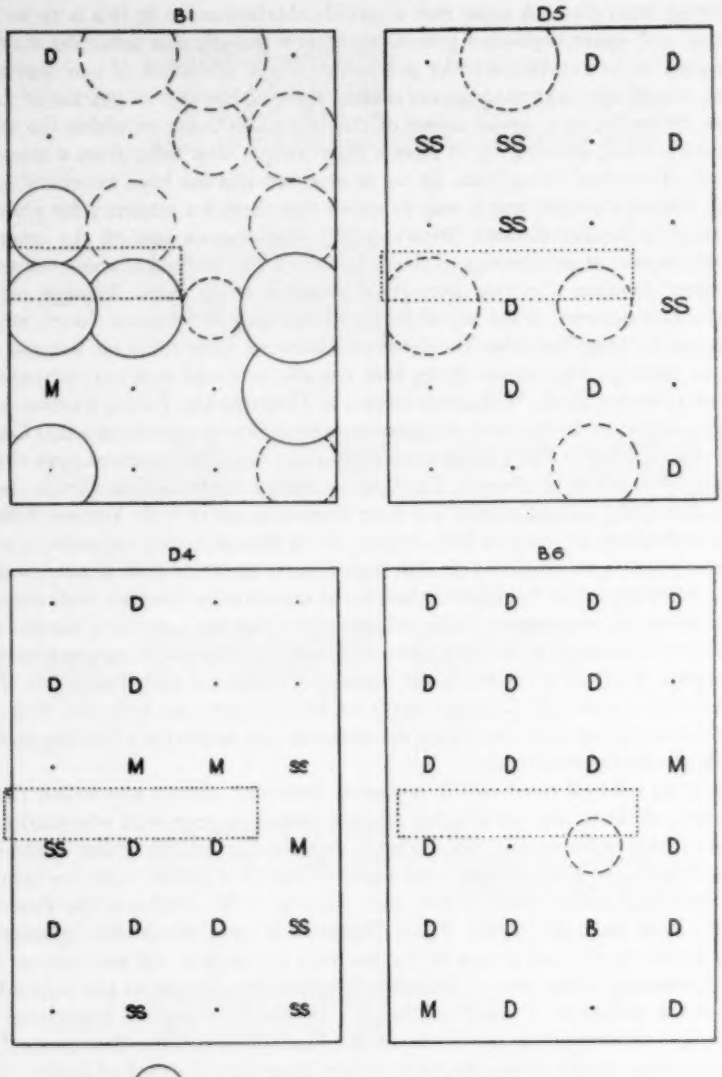


FIG. 2. Diagrammatic representation of root distribution of Corsican pine in relation to soil profile. Site referred to, Compts. 198 and 202, Staindale Forest.

suffering from die-back show that a considerable reduction in this is to be expected and under continued prevention of new growth this reduction may be expected to be cumulative. The prevention of the formation of new leaves is, thus, one of the important factors causing the development of patches of dead trees. Secondly, as a special aspect of this, situations occur in which the more successful trees, growing up to form a high canopy, may suffer from a renewed attack of terminal dying back. So far as observed this has been associated with high relative elevation and it may be noted that there is a tendency for pines so situated to become diseased (Brown, 1957). There was a case on the moor at Blubberhouses at an elevation of about 1,000 feet.; an interval of about ten years occurred between the two periods of terminal dying back. Another rather similar case occurred at the top of the very steep slope in Llanover Forest, which is known as Graig Pant Glas: the elevation is between 1,100 and 1,250 feet and the aspect easterly. Very severe dying back has also occurred in a strip planted at about 1,250 feet in the Whinlatter section of Thornthwaite Forest, Cumberland, and having a northerly aspect. It was noticeable in the two latter cases that Corsican pine planted at lower elevations and in more sheltered positions were either much less or not at all affected. The same association between high relative elevation and dying back of crowns has been demonstrated in Lake Vyrnwy Forest. The indications are that, at least in part, this is determined by exposure to cold winds. There is no absolute rule that high relative elevation shall determine die-back, however, and it would seem that, in the same way as there are local associations between situations in cold hollows and dying back, so local associations also exist between advective frost and dying back. European larch has also provided examples of this, e.g. on the upper slopes of Drummond Hill, Perthshire. The possibility suggested by Delevoy (1951) for Black pine on the Ardennes, that too cool a growing season at the higher elevations in this country is a limiting factor, needs also to be considered.

3. If an affected stand which is passing into high canopy and which shows a mosaic of more and less severely affected patches is examined edaphically, it seems always to be the case that the more severely affected areas occur on the less satisfactory soils. Examinations were made in Staindale Forest, with the help of the local staff, and in Slaley Forest, with the help of Mr. Forbes of the Forestry Commission Research branch. Fig. 2 illustrates the type of root development in relation to type of soil profile in various parts of Compts. 198 and 202 on the north-westerly facing slope of Staindale. The surface soil horizons (see Appendix) showed a podsol in a sandy soil, with a tendency to marked impedance in drainage and compaction in the base of the A and the top of the B horizons. The subsoils were of two types; the most widely occurring consisted of highly compacted material made up of angular sandstone fragments set in a slightly clayey sand; but in places the subsoil was very porous, freely draining, and consisted of large sandstone pieces in the interstices of which a certain amount of soil occurred. Reference to Table I will show that at the time of examination, in 1958, there was a fairly good association between rooting conditions and the condition of the trees, the very rocky, porous, but deeply rooted subsoil carrying the healthiest


B1
D
M
D5
D D
SS SS D
SS
D SS
D D
D
D4
D
D D
M M SS
SS D D M
D D D SS
SS SS
B6
D D D D
D D D
D D D M
D D
D D B D
M D D
Unaffected
Slightly affected
Moderately and severely affected
D Dead
SS Sitka spruce
M Missing
Soil Pit

stand. Diagrams which illustrate the then condition of some of the plots taken are shown in Fig. 3. The following points may be made with regard to this area: firstly, there was often a marked association between micro-relief on the slope and the presence of at least a few relatively successful trees; thus with the consolidated subsoil, a slight concavity of slope (D1, 3, and 5, Fig. 2; and Table I) was more favourable than a slight convexity (D2, Fig. 2; and Table I). One aspect of

TABLE I

Data relating to Severity of Disease and Distribution of Roots in Profiles cut in Compts. 198 and 202, Staindale Forest

Plot references	*Type of subsoil*	*Approximate total rooting depth (in.)*	*Depth of main rooting zones (in.)**	*Total conditions score (all dead = 96)*	*Number of trees out of 24, slightly or not injured*	*Number of trees per acre uninjured or only slightly injured*
B1	Loose, broken rock	36+	36	36	14	916
B2	"	36+	36	47	11	799
B4	"	36	13+	65	4	290
B3	"	41	4+12	81	0	0
D4	"	24+	5½	86	0	0
D5	Consolidated, slightly clayey sand; very stony	40	12	71	4	290
D3	"	31+	6½†	74	3	218
D1	"	42	3½†	77	3	218
B5	"	22	4½†	79	2	145
B6	"	22	3	90	1	73
D2	"	19	5	92	0	0

* The smaller depths occurred in the humus and/or the A horizons.

† Abundant root development deeply very locally.

Profile B3 showed two main zones of roots; an upper in the A_0 and A_1 and a lower in the B3 horizons.

this was that on the convexities roots of grasses and ling tended to dominate the humus and so exclude pine roots from an important part of the available rooting space (Appendix I); whereas in the concavities the pine roots successfully grew among the grass and ling roots, these plants themselves becoming more or less suppressed. Secondly, the absence of soil in the interstices of the large sandstone pieces (D4, Fig. 2; Table I) seemed to be of critical importance. Thirdly, plots on the same contour, and showing no appreciable difference in surface relief, varied in condition according to changes in soil conditions; e.g. a small area near to

FIG. 3. Examples of variation in stocking in the sites examined in Staindale, Allerston Forest (see Fig. 2 and Table I).

B1–B2, Figs. 2 and 3, but showing a similar type of soil and root development as D2, was a complete failure.

A similar state of affairs was revealed at Slaley Forest in an area of Corsican pine planted on a plateau, the relief of which, in the place examined, is almost flat: the elevation of the area is about 1,000 feet. This was originally heather moor. The underlying rock is Coal Measure sandstone. Either an iron pan or a gley pan may

TABLE II

Comparison of Bad and Good Patches in Corsican Pine, Slayley Forest (see Fig. 4)

Plot	*Crown density score**	*Soil*†	*Depth of mineral soil with obvious pine rooting (in.)*	*Ground vegetation*
A	6	8 in. fine sand over broken, soft, sandstone flags; freely drained	none obvious	Heavy mat of *Deschampsia flexuosa*
B	132	As A but 19½ in. deep	19½	Almost none: a little *D. flexuosa*
C	59	10 in., leached, gleyified, fine sand over hard pan; over compact clayey sand	7	Strong *Calluna vulgaris* with mosses
D	123	11 in. leached sand over 10+ in. stony loamy sand	21†	Suppressed *C. vulgaris*
E	12	7 in. leached sand over hard pan, over hard, compact sand	none obvious	Strong *C. vulgaris*
F	112	15 in. loamy sand over broken, soft, flat-bedded sandstone flags	15	Partly suppressed *Agrostis* spp., *D. flexuosa* and *Pteridium aquilinum*

* Based on weighting VT = 1; T = 4; MT = 9; MD = 16; D = 25 (see Fig. 4).

† General soil type is a podsol with a locally occurring thin pan and local gleyification. All overlies freely drained Millstone Grit. Elevation O.D. is about 1,000 ft. on a flat plateau.

occur; but even in the absence of pan the subsoil is unfavourable to root development and the main rooting space shallow (Appendix). Three comparisons made in adjacent 'good' and 'bad' patches are given in Fig. 4 and Table II; corresponding profile descriptions are given in the Appendix and it will be seen that the relatively good areas have an advantage in character of rooting space over those severely affected. An examination in Wykeham Forest, on the Yorkshire moors, with the aid of the research forester, Mr. Wetherell, gave similar results; this was also on a plateau site which was originally heather moor.

4. It may be seen from the above that at least on some sites on which terminal die-back has occurred there is evidence that conditions for root development and action also act to cause disease. It seems to be quite clear that this aspect of disease often occurs together with terminal dying back. Thus the examination of stands which were unthinned but were passing into a condition of high canopy showed

Comparison of Crown density in adjacent pairs of plots, in bad and good patches in Spacing Experiment ($4\frac{1}{2} \times 4\frac{1}{2}$ *ft.*), *Planting Year 1936. Slaley Forest (see Table II)*

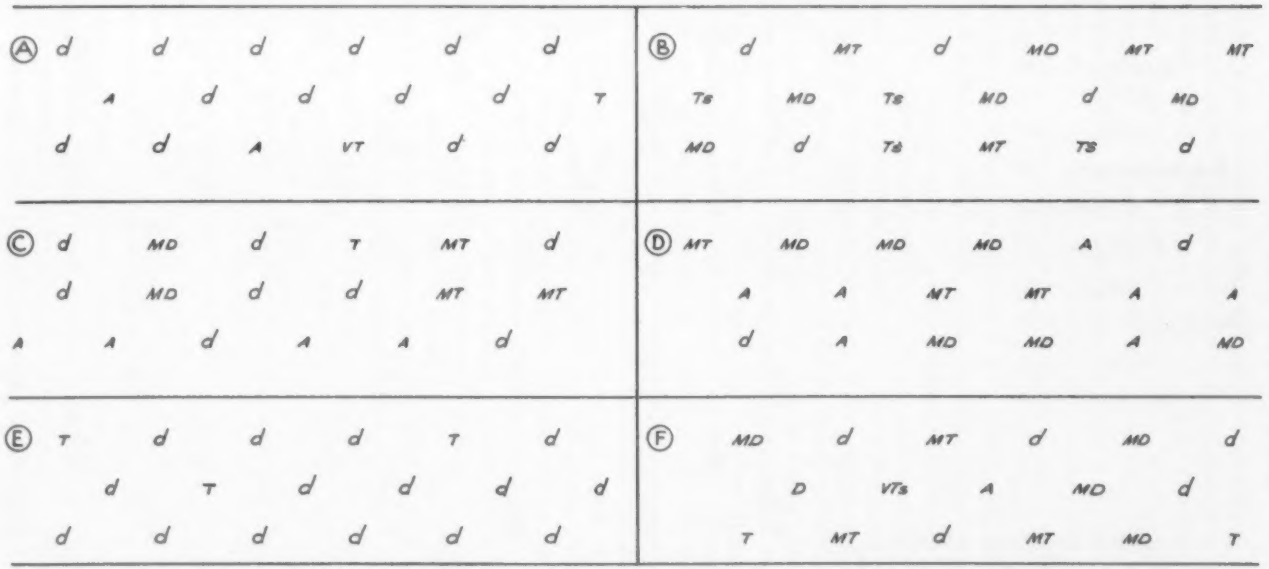

Ⓐ d d d d d d
A d d d d T
d d A VT d d
Ⓑ d MT d MD MT MT
Ts MD Ts MD d MD
MD d Ts MT TS d
Ⓒ d MD d T MT d
d MD d d MT MT
A A d A A d
Ⓓ MT MD MD MD A d
A A MT MT A A
d A MD MD A MD
Ⓔ T d d d T d
d T d d d d
d d d d d d
Ⓕ MD d MT d MD d
D VTs A MD d
T MT d MT MD T
Symbols :– D = dense, M = moderately, T = thin, V = very, d = dead, A = missing, S = suppressed

FIG 4. Examples of stocking in adjacent good and bad patches in Corsican pine in Slaley Forest (see Table II).

Staindale Forest Compt. 116, Planting Year 1935, Plots 1 and 2, Sept. 1958
21 ← Total Height ft.
T ← Crown Density
V. Sl. ← Degree of Dying back
A = Missing
d = Dead
WT = Wind Thrown
T = Thin
D = Dense
V or V. = Very
M = Moderately
nil. = none
Sl. = slight
Sv = severe

FIG. 5. Diagrams showing condition of 24 years planted Corsican pine on a plateau site (elevation *c.* 800 ft. O.D.) in Staindale Forest Compt. 116.

Soil. A podsolized sand showing 3 in. A_0; 3–6 in. of A, over solid, massive, stony B horizon. Hard pan occurs in places.

Grouped Vegetation: *Dryopteris dilatata*, *Calluna vulgaris*, and a little *Epilobium angustifolium*, usually showing no suppression. The dying back occurred on the lower branches; terminal dying back had occurred on the smaller, now dead trees. The period since dying of trees began was about 12 years.

Date of recording—September 1958.

that disease in the form of terminal dying back had become obvious when trees were about eight feet in height and was still proceeding in the form of developing crown debility when the dominants were 25 to 30 feet high. An example is given in Fig. 5 which shows two small plots taken in Compt. 116, Staindale Forest. This is a plateau site on what was originally heather moor. There is a slight slope down to a hollow in which die-back has been severe, but in the area sampled, above this, little was seen except on the lower branches of crowns. It will be seen that the surviving trees are dominants or codominants: there were no living smaller trees. On the whole, the taller trees had the more densely foliated crowns; but a high proportion of the living crowns were thinly or very thinly foliated. There is no doubt that at the time of examination, trees had been dying over a period of about twelve years. The soil on this site (see Appendix) is a podsol with a shallow depth of leached sand which overlies a very compact, massive, B horizon. Root development is shallow and a certain amount of windthrow has occurred because of this. The course of disease appears, therefore, to have begun with death of terminal shoots and to have proceeded to loss of foliage density accompanied more or less by death of shoots on the lower, but not critically shaded, branches. It needs to be remembered that many at least of the crowns so affected were not in any way crowded or suffering from lack of light; nor does there appear to have been any critical infection or scorching of needles. It would appear thus that the deficiencies of the site for root development and action, acting after the original dying back of terminal shoots, were causing a wide opening of the stand with the consequent development of a strong ground vegetation which consisted largely of ling (*Calluna vulgaris*). This is to be taken thus as an example of the early opening of a high canopy, here beginning with a small size of tree, which occurs naturally in forest on soils of poor supply and may be observed in many places in native Black pine forest when site conditions are suitable (Day, 1959).

5. This sequence of development from terminal die-back to loss of foliage density is to be observed on a number of types of site. This seems to have been the history of the Corsican pine in Compt. 84, Dalby Forest. This stand is on an easterly facing upper slope of about 20° in Dalby Dale. The soil (see Appendix) is shallow and overlies broken, very freely draining, hard limestone. It is a black rendzina in part and then is practically a stone soil, or lithosol; but in parts there is a thin covering of brown sandy clay. The dominants were in 1959 about 45 to 50 feet in height. The stand had suffered from terminal dying back when in the thicket stage; the affected places were cleaned and replanted with beech which in 1959 were about 15 feet in height. The remaining parts of the stand mostly grew up more or less successfully, but eventually began to show loss in foliage density, often with shoot die-back on the lower part of the crown. Severely affected trees eventually show a general browning of needles and die. Examination of such trees when near to death showed that the main stem was still alive and also the main larger roots: death had plainly set in on the root extremities. The examination of nearby relatively healthy trees supported this. They showed no dying back of the crown; but that it had been common for death of the smaller roots to occur. This takes place, at least sometimes, during periods of root

extension, and so long as a tree is adequately vigorous subsequent regrowth of roots takes place. Another aspect of importance is seen in the tendency for roots of the ground vegetation to dominate the shallow depth of surface soil: the roots of the pine are, in consequence, largely compelled to develop in the stone brash below, in the interstices of which there is commonly little material for root occupation. Scots pine in this forest, on a similar calcareous stone soil, have shown a similar type of stand development and this suggests that it is natural to sites of this type for these two species of pine, at least, in an east of England climate.

Dominance of the surface soil by roots of ground vegetation, to the exclusion largely of pine roots, has been observed on sites with shallow soil in a number of places: e.g. in Staindale Forest, on the plateau, with a mat of Heath Wire grass (*Deschampsia flexuosa*) and bracken (*Pteridium aquilinum*) on a shallow sand overlying limestone; the pines were 20 to 25 feet high: also on a shallow black rendzina overlying broken limestone, at Blairquhan, Ayrshire, with Dog's Mercury (*Mercurialis perennis*) as the dominant plant in the ground flora, under rather open pines of about 45 feet in height: and again in podsolized moor soil in Slaley Forest with a ground vegetation which consisted mainly of ling or Heath Wire grass, in pine then approaching the thicket stage: further, on a shallow leached sand soil overlying Coal Measure sandstone on a plateau in Llantrissant Forest, with mainly Bent grass (*Agrostis* spp.) and bracken under pines then about 25 feet high. Such susceptibility to competition need not occur, and there are suggestions that it arises, at least in part, owing to inadequate water supply. The very fact that in the early stages of development of a stand, a high closed canopy is unable to prevent the development of such ground vegetation, is itself a demonstration of the unsatisfactory site conditions endured by the trees.

6. Crown condition within stands which show no, or inappreciable, dying back seems to be related directly to conditions for root development and action. Stands on areas of relatively even and satisfactory soil conditions, such as, for example, may be found in Delamere Forest, Cheshire, but also in many other places in the centre and south of England, and which are subject to treatment by thinning, show a regular and satisfactory density in stocking and relatively even crown size and condition. Variations occur, not merely from tree to tree, often according to degree of dominance, but also from patch to patch indicating variations in soil condition. These, however, are not critical and present no real silvicultural problem. Areas of inferior site quality, such as that of the plantations in Llantrissant Forest, of 37 years of age, on rather shallow, leached, sandy soils overlying Coal Measure sandstone and situated on a hill top at about 800 feet, still may show fair regularity in stocking: but the stands tend to be less dense, taking comparable stages in development, and the difference in crown condition is obvious when comparison is made with stands on better sites. The taller, or dominant, crowns tend to be both the most densely foliated and the deepest; the codominant crowns to be only moderately dense and often, in depth of dense crown, markedly shallow: they also often include an appreciable proportion of trees in which the crown is entirely thinly foliaged. These differences in crown condition can arise even if there is ample individual growing space considered geometrically. If soil condi-

tions become poorer still, and particularly if this happens in an irregular fashion so that a mosaic of poorer and better areas of soil occurs, a definite patchiness in condition of stand develops. Parts of the 32-year-old Corsican pine stands in Bennan Forest, Kirkcudbrightshire, illustrate this. The soil as seen is a brown podsol and contains many granite stones; in places at least it is massive in structure and compact. Patches which contain trees with crowns in poor condition are often common and their occurrence cannot be explained either by excessive stand density or by removal of the larger and better trees in thinning; they are plainly determined by site conditions. Occasional trees can be found dying from root infection in these patches, probably with *Fomes annosus*. *Armillaria mellea* may act in the same way: this has occurred in the Wythope section of Thornthwaite Forest, Cumberland. This tendency on poor sites to form an irregularly open stand, when a high canopy has been attained, seems to connect with Wright's (1957) experience that heavy thinning in Corsican pine making poor growth on sand dunes resulted in a delay in drying out of the zone rooted and in a temporary improvement in levels of K, Mg, and N in the foliage. In effect, such a thinning tends to occur naturally, until a satisfactory level of supply has been reached.

7. The tendency for Corsican pine stands, in which terminal dying back is absent or inappreciable, to show a mosaic pattern in which patches of poorer development show a failure to maintain adequate crown vigour and a tendency for trees to die, even though not actually suppressed, connects directly with what has been demonstrated for Allerston and Slaley Forests in areas in which dying back of the crown has been serious, but in which failure has occurred to varying degrees and in patches. On the other hand there seems to be no connexion with the more fertile, moist, hollow sites in which severe damage, or complete failure, through terminal dying back occurs: these are clearly frost hollows. It is not so easy to separate the upper exposed edges of steep slopes, on which terminal dying back is sometimes serious. These are certainly sites on which dying back from water shortage sometimes occurs; but they are also sites, given a suitable aspect, on which injury by advective frost during periods of cold wind may occur. It is of interest to note that European larch (*Larix decidua* Mill.) suffers from dying back and canker on these two types of site and sometimes this has happened side by side with similarly diseased Corsican pine. There was at one time an example of this on the edge of one of the high ridges in Glentress Forest, Peeblesshire, and similar evidence has been obtained over a period of time in Llanover Forest, Monmouthshire. The association of larch canker and die-back with frost hollows is well known.

CROWN DEBILITY

1. The two aspects of crown disease discussed here warrant some further consideration and certainly further research. The effect of terminal dying back depends on the proportion of shoots killed, the degree to which they are replaced, and the extent to which the debility caused by injury predisposes to infestation by bark beetles or infection by fungi. The basically important factor, under these conditions, in determining crown debility seems ordinarily to arise

through the prevention of the development of new leaves. The case is different when loss of crown condition develops through reduction upwards from the crown base of the depth which is densely foliated. Part of the evidence for this is seen in the condition of the bark. The bark of the live parts of a crown newly

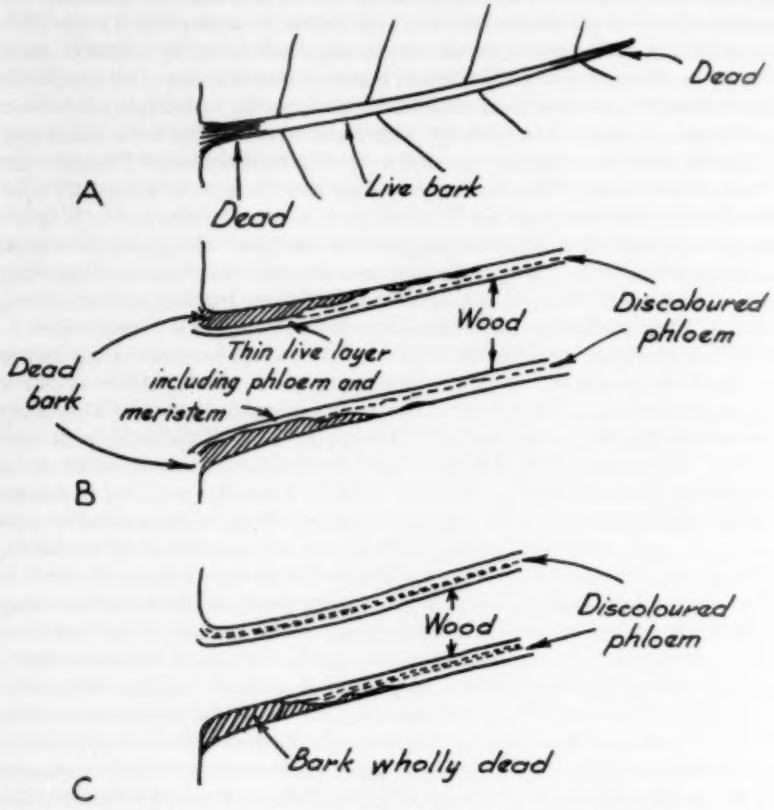


FIG. 6. Diagrams illustrating the dying of bark at the base of lower branches on Corsican pine. A, dying branch 0·5 in. diameter at base, on the lower crown of a moderately severely affected tree openly grown. B and C, bases of branches with dead terminal shoots but bearing many live needles: both were in the lower crown but unshaded.

affected by terminal dying back, in a situation in which frost is suspected as the cause of injury, if cut, shows the slightly creamy colour characteristic of healthy tissue. The indications are that the killed tissue had been normally healthy at the time of death. If the bark is examined, of a branch which is on the lower part of a crown which shows loss of foliage density from the base upwards, it will be seen that the distal shoots and nodes show a normal coloration of bark; but that increasingly as the base of the branch is approached, a brown, or brown-red,

coloration appears in the phloem. There is no need for a branch so affected to be shaded: the condition seems determined by its vigour as expressed in growth and leaf equipment. The branch base is almost always the most severely affected; but it may often be seen that there is a tendency for discoloration to be accentuated at nodes. An associated phenomenon is the occurrence of unduly early dead outer bark, most commonly at the base of a branch and there usually on the underside; but also sometimes at the lower nodes which are of course places of collection of secondary branch bases. Sometimes death takes place through to the cambium; and then a small canker develops (Fig. 6). Moribund lower branches often show this phenomenon in an acute form: bark at the base of the branch may be dead and also that on the distal parts, while the central part of the main stem of the branch may be still living; this may happen on an outside branch not subject to suppression by other trees (Fig. 6).

2. There are indications thus that the base of a branch and the node at which it is situated develop as regions of physiological stress to a greater degree than those parts which are nearer to the terminal growing-points. If this is so then it would appear to be equally probable that the inner and lower parts of the crown will first of all show signs of debility under stress of shortage of supply, then the terminal points of the lower branches, and last of all those of the higher branches. This is actually what is to be observed in a suitably affected stand, not only of Corsican pine, but also of other species of tree.

The simplest explanation of this, though not necessarily a complete one, is that a stress arises for water supply. If sufficient water is not available to support the whole crown, the terminal growing-points will be supplied at first, in preference to parts nearer to the main stem, those on the upper part of the crown receiving preference over those on the lower. This appears to be a general rule in trees. Thus evidence was obtained in eucalypts which were under stress for water supply that branch bases suffered before the distal parts, though to external observation the latter ordinarily show the first obvious signs of distress (Day, 1959). Essentially similar indications are obtained from Douglas fir when suffering from bark necrosis of which a necrosis of the phloem is typical (to be described in another publication). The discussion by Løfting (1959) on crown development in Silver fir (*Abies alba* Mill.) on a climatic limit determined by dryness is of interest in this connexion and also the observation of Georgescu and Catrina (1957) that diminution in moisture content in the main stem of an uprooted Black pine begins at the base and progresses upwards. It is reasonable to take it that the same would be observed in a standing tree the soil-water supply of which had failed.

3. If insufficient water supply is a principal and basic cause of loss of foliage density in the crown of Corsican pine, it seems to be clear that conditions determining this may be various. Nutrient deficiencies as affecting root development could plainly be one aspect of this complex; infections could present another; or in any given climatic conditions, the physical character of the material available for root occupation might be the important source of deficiency. It is probable that all three aspects, that is, the nutritional, the biotic and the physical, enter

into this matter; but so far as field examination can determine, it seems to be quite plain that physical conditions are usually the most important: the profile descriptions in the Appendix suggest this. The association between loss of crown condition and physical soil character seems in fact to be general and may be found on deeply rooted as well as shallowly rooted soils; e.g. sand soils which are of poor physical structure but permit of deep penetration, though without efficient soil occupation, may provide examples of this: extensive dying back of roots has always occurred in the examples seen.

Granted the importance of physical and often chemical soil conditions, the problem of root infections has still to be dealt with. Field examination shows that ordinarily loss of foliage density is related to failure to maintain adequately the feeding root complexes. Thus in root systems excavated in various parts of Allerston Forest the larger roots were found to be living even on severely affected trees. It was the smaller roots that had died, and examination of the more healthy trees which still have moderately good crowns commonly has shown that untimely death of the smaller roots has taken place; this is a matter which of course needs to be checked quantitively and in relation to the proportion of live roots maintained. This dying of the smaller roots may be related to physical soil conditions. It has been observed, for example, in calcareous stone soils, and Rennie (1956) discovered that poor aeration is one of the physical imperfections of Allerston moorland soils. It has been shown for other species of pine (Campbell and Copeland, 1954; Sutherland *et al.*, 1959) that such conditions may favour the development of infections. Also it is possible to isolate *Pythium* species from calcareous soil in affected areas in Allerston Forest. Infection trials with small trees grown in sterilized soil water have demonstrated that, under the conditions of inoculation, some of these fungi are capable of causing infections of Corsican pine roots, as well as of those of Sitka spruce and Douglas fir. It may be suggested, therefore, that in this direction may be found additional factors helping to cause loss of foliage density and eventually often death of trees.

CONCLUSIONS

1. Two general types of disease of the crown of Corsican pine have been discussed. They may develop separately, but may be found together. The one entails a dying back of terminal shoots, or sometimes the top of a tree, and is characteristic of plantations which have entered the thicket stage. This type of injury is regarded as being based on either frost injury or water shortage. Frost injury may occur through the pooling of cold air, or through exposure to cold winds, and either in the spring or at the end of the growing season which, for the cambium in terminal shoots, extends from early spring until early autumn. Water shortage has acted acutely, in the specimens examined, from about midsummer onwards and characteristically on sites which by physical shape are water-losing and which have subsoils which are a poor source of water supply (see Appendix). The dying of the top of the tree under water shortage typically occurs in the thicket stage in stand development and tends not to occur later; this is characteristic also of Japanese larch when grown on similar sites.

2. The other general type of disease shows itself as a loss of foliage density which develops from the base of the crown upwards; it is characteristic of stands which are forming or have formed a high canopy. It is regarded as determined by a deficiency in supply from the soil, mainly of water, and the manner of its development to be caused by the inherent tendency in a tree in the face of such shortage to maintain supply to the terminal growing-points and particularly those at the top of the tree, in preference to parts of the plant body nearer to the root. There are, of course, limits to which this can be maintained. The causes of supply deficiency are essentially edaphic and probably principally to be found in the physical character of the soil. Nutrient availability and root infections seem, however, often to play a part; but the exact character of the complex of conditions acting remains to be determined and may vary from site to site. A dying back of shoots on the lower branches is often an accompaniment of loss of foliage density and marks the increasing decrepitude of the crown. Eventually the whole crown may turn brown and die.

3. Anatomical studies provide evidence that the critical factors which cause death of tissues in terminal dying back are physical and that they act during the growing season. Death of trees the terminal shoots of which have been mostly, or entirely, killed is regarded as being determined largely by the prevention of the development of new foliage. The killing of terminal buds and shoots is followed by development of adventitious shoots. Some of these can develop into new branches, but observation in areas in which disease has been severe shows that, very often at least, they all die, so that no adequate new leaf equipment develops to replace existing foliage.

4. Infestations are plainly sometimes of importance in determining the final condition of a stand. Thus the larger Pine Shoot beetle, *M. piniperda*, may bore and destroy most, or all, of the remaining new shoots which are developing on a crown, whether affected by terminal dying back or loss of foliage density. Similarly *Ips* or *Pissodes* species may colonize the main stems of trees the tops of which have died owing to water shortage. No assessments of the effects of these infestations have been made; but there is no doubt that they occur and locally, at least, may be of importance.

5. It is more difficult to assess the importance of bark infections. Anatomical study suggests that in the critical stage of terminal dying back they are of little importance. There is no doubt, however, that injured parts are rapidly colonized by various mycelia of which *S. abietina* is one. Other species of fungus occur, however, sometimes much more abundantly, and it would appear that there is a need to study the succession in microfloral colonization which takes place on injured trees. The possibility of parasitic action on more or less seriously damaged trees seems, however, to be considerable, and it would appear that the importance of *S. abietina*, *C. ferruginosum*, and other fungi is to be found in this field.

6. The conditions of the crown of Corsican pine which have been discussed are seen thus to be based on adverse climatic or edaphic factors. Biotic factors may have some primary importance: as beetle infestations in the presence of large populations, or root infections which help to create supply deficiency to the

crown. Bark infections seem to be of secondary importance and any demonstration to the contrary needs to be based on clear evidence as to the process of development of disease in the field. The position of Corsican pine as an exotic, moved to north temperate latitudes, has not been discussed, but the relative absence of terminal dying back in the less elevated eastern and southerly parts of Britain suggests that in terms of susceptibility to frost injury this pine is on its climatic limit. There seems to be a distinct possibility that temperature conditions in a northern climate are of importance in this connexion as tending to favour a long growing season, at least in terms of cambial activity in currently formed shoots. The susceptibility of Corsican pine to loss of crown condition on sites with difficult types of subsoil, though not having surface soil horizons particularly infertile, suggests also that in terms of rainfall it is not far from a climatic limit. Much of its success in eastern and southern England must thus be related to the presence of relatively satisfactory conditions of soil supply, irrespective of character of season. Experience shows that where these fail, as, for example, on deeply rootable sand soils of poor physical structure and adverse to intensive root occupation, Corsican pine also tends to fail, showing characteristic loss of crown condition which reflects a dying back of the root system, when an appropriate stage in stand development has been reached. The classification of varieties of Black pine in Belgium (Delevoy, 1951) into order according to growth vigour and frost susceptibility is of interest as suggesting the genetical heterogeneity of this species in reaction to climatic conditions in north-western Europe.

7. In this discussion the influence on the crown of strong winds, or salt-laden winds, or of infections or infestations of leaves, has not been taken into consideration, and the aspects of disease discussed are regarded as able to occur without the aid of any of these things; though of course any damage suffered through their action can be of no benefit.

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APPENDIX

Short Descriptions of Soil Profiles relating to the pages referred to

Page 155. Generalized descriptions of main profile types seen in Compts. 198 and 202, Staindale Forest, E. Yorkshire

A. A soil type found on a moderately steep to steep north-westerly facing, upper slope in Staindale

Layer No.	*Depth (in.)*	
1	—	Litter and fermenting litter of pine needles, grass, and bracken.
2	2·0–9·0 variably	Humus, the lower part being peaty and completely amorphous.

Layer No.	Depth (in.)	
3	1·5–2·0	Black sand rich in intimate humus; structureless; clearly defined from:
4	5·0–9·0 variably	Grey sand, compact, structureless, often stony; sometimes showing gleying in the lower part and very hard; clearly defined from:
5	0·2	Black, indurated, humus deposition layer; sometimes absent and very shallow.
6	0·2	Deep orange-brown, indurated iron deposition layer sometimes absent and very shallow.
(or 5–6A	2·0	Mottled grey and brown, indurated, sand, often stony; usually with the base of layer 4 constituting a zone of impedance.)
7	up to 30·0	Yellow-brown sand in the interstices of sandstone blocks of up to 10 inches across; loosely aggregated and freely drained. This merged into:
8	—	Brown-grey, or yellow-grey, sand occurring very sparsely in the interstices of similar sandstone blocks.

Notes: Layer 7 may show interstices practically free from soil; growth is then poor; or a layer of consolidated, stony, sand may occur between it and layers 5 and 6; growth is then also poor.

The pan (layers 5 and 6 or 5–6A) is usually penetrable.

B. A soil type found on a moderate to steep middle slope below A

Layer No.	Depth (in.)	
		Layers 1 to 6 are much as in A. Ling debris may occur in the litter.
7	variably 12 to 30	Yellow-brown slightly clayey sand forming a matrix in which occur numerous angular sandstone fragments; locally penetrable but usually very consolidated and structureless; this merged into:
8	—	Yellowish-grey similar material having similar physical properties.

Notes: Layer 4 may be very stony, consolidated, and unrootable; very poor growth then occurs. Most roots occur in layers 2 to 4. Occupation of 7 to any considerable extent was associated with dominance and survival. The pan is usually penetrable.

Page 161. Compt. 116. Staindale Forest, Planting Year 1935

SITE: A gently undulating plateau of about 800 feet elevation.

Layer No.	Depth (in.)	
1	3·0	Organic surface covering (mor).
2	3·0–6·0 (variable)	Dark grey humus-stained structureless sand; firm but penetrable.
3	2·0	Medium grey very hard structureless sand.
4	0·25	Black indurated humus pan.
5	0·25	Deep orange-red indurated iron pan.
6	4·0	Medium orange-grey very hard sand.
7	5·0+	Deep orange-brown sand in the interstices of angular sandstone fragments; hard; massive; consolidated.

Notes: Drainage through layers 2 to 6 is slow: these layers are, locally, more or less missing. Rooting is shallow and mainly confined to layers 2 and 3, or the top of 7 if 2–6 are missing: scattered wind-throw has occurred.

Page 161. Typical soil profiles in Compt. 84, Dalby Forest

Layer No.	Depth (in.)	
1	0·5	Litter and fermenting material of pines, herbs, ferns, &c.
2	0·1	Brown-black mull humus.
3	4–11 variably	Black crumbly loam, 50 per cent. small limestone pieces; loose, friable, porous; this merged into:
4	20·0+	Hard broken limestone fragments with a little pale brown gritty material in the interstices.

Notes: Pine roots occurred mainly and abundantly in layer 4, in stone interstices. They were frequent in the base of layer 3 but the upper part of this was dominated by roots of the ground vegetation. Death of small roots had occurred commonly in layer 3, from a tree with a good crown. Death of root cortex was common in layer 4 on roots of $\frac{1}{8}$ inch diameter and larger.

As a variation of the above, layer 3 was replaced with a sandy clay of about 12 inches depth, dark grey-brown at the top, becoming light orange-brown and containing fragments of limestone and sandstone.

Ground vegetation. On limestone: *Mercurialis perennis*, *Brachypodium sylvaticum*, *Rubus fruticosus*, and *Ligustrum vulgare*. On sandy clay: strongly growing *Rubus fruticosus*.

Page 158. Comparison of adjacent profiles in Slaley Forest, Spacing Experiment (A & B; C & D; E & F)

Planting year 1936. Planting distance $4\frac{1}{2} \times 4\frac{1}{2}$ ft.

Site: An almost flat plateau at about 1,000 feet O.D. General vegetation type: *Calluna vulgaris* with *Deschampsia flexuosa*.

PLOT A

Layer No.	Depth (in.)	
1	1·5	Organic covering mainly of grass litter under a *D. flexuosa* mat.
2	3·0	Brown-black fine sand with much intimate humus; soft, friable, and containing leached sand grains. This merged into:
3	5·0	Medium red-brown fine loamy sand, soft, friable, 50 per cent. soft sandstone fragments; this merged into:
4	3·0	Medium red-brown fine loamy sand, soft, friable, porous, gritty, in the interstices of soft sandstone pieces; this was clearly defined from:
5	—	Flat bedded soft sandstone flags with a little compact sand in the interstices.

PLOT B

1	1·5	Litter and fermenting material of pine and grass.
2	9·5	Dark red-brown fine sand: soft, friable, porous, structureless; clearly defined from:

Layer No.	Depth (in.)	
3	10·0	Medium yellow-brown gritty fine sand containing about 15 per cent. stone; locally soft and friable, locally moderately compact, porous; clearly defined from:
4	—	Soft, obliquely set, sandstone flags: very firmly set.

Notes: There was a dense mat of *Deschampsia flexuosa* on A; but only a very little grass on B, under a dense canopy. A main difference between A and B lies in the depth of freely rootable material: this includes layers 1 to 3 in both profiles with comparable depths of 9·5 and 21·0 inches.

PLOT C

Layer No.	Depth (in.)	
1	1·0	Organic covering mainly of ling litter.
2	7·0	Very dark grey fine sand with much intimate humus; soft, slightly friable, massive; this merged into:
3	3·0	Very dark red-brown patched with dark brown-grey fine sand; very firm, moderately hard, massive; this merged into:
4	1·0	Dark red-brown stony indurated pan: this was clearly defined from:
5	6·0	Medium fawn-brown clayey sand; stony, massive, very firm; moderately hard, compact; this merged into:
6	—	Medium yellow-grey clayey sand, 50 per cent. stones; physically much as layer 5.

PLOT D

1	2·0	Organic covering mainly of litter and fermenting material from pines and ling.
2	6·0	Very dark red-brown sand with much intimate humus and about 15 per cent. stones; soft, friable, porous; this merged into:
3	5·0	Medium brown-grey clayey sand, firm, compact, porous; this merged into:
4	10·0+	Medium grey-brown loamy sand, firm but slightly friable, porous and in the interstices of small subangular stones.

Notes: Most of the root development occurred in layer 2, in both profiles C and D; but in D pine roots of up to ¼ inch diameter occurred to below layer 4. D was thus the more deeply rooted and the better drained.

PLOT E

Layer No.	Depth (in.)	
1	1·0	Organic covering mainly of loose ling litter.
2	7·5	Very dark grey fine sand with much intimate humus; soft but firm; structureless; porous; clearly defined from:
3	0·5	Brown-red stony iron pan, hard, brittle, not cemented; clearly defined from:
4	9·0	Medium yellow-brown loamy sand; very firm and compact; massive; this merged into:
5	—	Medium fawn-brown material similar to layer 4.

PLOT F

Layer No.	Depth (in.)	
1	2·5	Organic covering mainly of grass litter with pine needles.
2	7·0	Dark red-brown fine loamy sand, 10 per cent. stones; soft, friable, porous; clearly defined from:
3	8·0	Medium yellow-brown fine loamy sand, 20 per cent. stones; porous; mostly compact and massive; clearly defined from:
4	—	Soft sandstone flags with fine sand firmly set in the interstices.

Notes: Obvious pine roots occurred only in layer 2 in profile E but into layer 4 in profile F. Layer 4 in E is slow-draining.

THE NATURAL WOODLANDS OF GALLOWAY AND NITHSDALE

JOHN GLADSTONE
of Capenoch

SUMMARY

An account is given, from contemporary printed sources, maps, and personal observation, of the woodlands of the south-west of Scotland as they existed at the end of the seventeenth century, together with notes on their subsequent history.

THE only truly native pinewoods in Great Britain are to be found north of the Forth and Clyde Canal, but much natural woodland of broadleaved trees existed, and some still exists, in the south of Scotland, particularly in Galloway and Nithsdale. This was composed of oak, mixed with other species such as ash, wych elm, birch, rowan, hazel, holly, and juniper. Evidence of its presence in the past is to be found in books, manuscripts, old maps, place-names, and on the ground.

Probably very nearly the earliest topographical description of Galloway was made by the Rev. Andrew Symson; it was written about 1684 when he was Minister of the parish of Kirkinner, in Wigtownshire. The manuscript, in Symson's own script, is in the National Library of Scotland, Edinburgh; it was not printed until 1823 when it was edited, anonymously, by Thomas Maitland of Dundrennan (b. 1792, d. 1851), a Lord of Session as Lord Dundrennan. Printed as appendixes are additional descriptions of Galloway and of various parts of it, and also an account of the Presbytery of Penpont, which covered mid and upper Nithsdale, and to which reference will be made later.

At the time when Symson wrote, the only planting of trees which had been done in south-west Scotland was in the immediate vicinity of lairds' houses. Symson tells us that many of the 'considerable houses' on the east side of the Water of Dee in the Stewartry of Kirkcudbright were 'deckt well with planting'. Those also on the west side 'have many of them much planting about them'; farther west, in Wigtownshire, the 'considerable' houses, of which a list is given, were said to be 'generally deckt with planting'.

One of the earliest planters of trees in the district seems to have been that remarkable character Andrew Heron of Bargaly (b. *c.* 1660, d. 1740) who wrote the greater part of the description of the parish of Minnigaff, which is printed as an appendix to Symson's *Description*. He does not refer to his own work as a tree planter except to say that he had at Bargaly 'a great many evergreens, both foreign and exotick'; he mentions, however, a house belonging to the laird of Polgown, on Loch Trool, which was 'surrounded with pretty groves of Scots pines, black cherries and other kinds of planting'; also the house, no doubt Kirroughtree, belonging to his nephew Patrick Heron, with grounds 'all devided and adorned with large thickets of fir and other planting'. He writes of his nephew making an archaeological discovery at Machermore, in the same parish, when 'one day making pitts for a plantation of firs'; and he also records that Machermore, 'a very agreeable seat', has a 'large plott of fine fir planting'.

The only mention of planting in Wigtownshire in the *Description* is on a an island in the White Loch of Loch Inch, which is said to have been 'planted with trees'.

There are no references to woodlands or trees in the south-west of Scotland in Sir Robert Sibbald's addition to Camden's *Britannia* (1695). Of Hume Brown's (1891) Scottish travellers, only two mention woods in our area. Sir William Brereton (1636) writes: 'There is very little or no timber in any of the south or west parts of this Kingdom [Scotland], much less than in England.' Richard Franck (1656) describes Galloway as 'inriched with plenty of rivers and rivulets, woods and groves'.

There are, however, a number of references to natural woodlands in Symson's *Description* and in the appendixes, particularly in the account of the Presbytery of Penpont. Beginning in the west, it is clear that in Wigtownshire little natural woodland remained at the end of the seventeenth century. 'In the shire of Wigton', Symson writes, 'we have neither coal, nor limestone, nor free stone, nor any wood considerable, except planting around gentlemen's houses.' But place-names indicate that woods existed in earlier times; for example, there are, in the parish of Kirkcowan, Kildarroch 'the church or chapel of the oak trees' and Barskeoch 'the hill of the wood or trees'; and, in Kirkinner parish, Capenoch 'the field of the tree stumps'. Symson writes of a 'large moor, called the Forest Moor, between Kirkinner and Sorbie'; he did not know why it was so called 'except it be, as the people say, because there was long since a great wood growing thereon, though at present there is not one tree growing there, unless 2 or 3 bushes may be called so'. This is no doubt the area marked on modern maps as 'The Forest'; it formed part of the Galloway Estate and had been planted by them; the trees were subsequently felled and the land was acquired by the Forestry Commission in 1934. It has since been replanted and is now known as Kilsture Forest.

The only other reference to woodland in Wigtownshire is at Park, near Glenluce, which Symson calls a 'very pleasant dwelling, standing on a level height in the midst of a little wood'. The old Castle of Park is still surrounded by trees, now also the property of the Forestry Commission.

Crossing the Cree into the Stewartry, we find numerous references to the Wood of Cree, or Cree Wood, that tract of land—lying to the west of the Water of Cree and north of Minnigaff—in which there is still much natural woodland. Symson tells us that the Earl of Galloway owned 'an excellent oak wood in the parish of Minnigaff lying upon the Water of Cree, 2 miles above the Kirk and town. This wood will be 2 or 3 miles in length and hath good timber in it, from whence the greatest part of the shire of Wigton furnish [i.e. obtains] timber for the building of houses and other uses.' He says that Wigtownshire is 'supplied with timber for building from the Wood of Cree in Monnygaffe parish which yields abundance of good strong oak'. These statements confirm the absence of woodland in seventeenth-century Wigtownshire and emphasize the importance of the Wood of Cree as a source of timber supply.

In Andrew Heron's account of the parish of Minnigaff the Wood of Cree is described as 'a very long tract of fine wood growing along the side of the river,

where it forms itself into a lake called the Loch of Cree'; he also writes: 'On the east bank of this loch [the Loch of Cree] grows that excellent oak wood'; and 'on the west side of the Loch, in the parish of Penygham [Penninghame] William Stewart [of Castle Stewart] hath a wood, which in time may produce good timber; but it is far inferior to the other [i.e. the Wood of Cree].' The Wood of Cree is marked on Timothy Pont's map [1654]: it would appear that the wood remained in existence until about 1875 when it was 'cut down by the then [10th] Earl of Galloway [b. 1835, d. 1903] who obtained 6,000 guineas for the timber'. 'This, of course,' according to a contemporary writer, 'destroyed its primitive grandeur. It is now principally copsewood which with growing, and some of the old, timber left, to some extent conveys an idea of what it must at one time have been.' The present writer recently visited the area and formed the impression that it could still be re-established as an oak wood; the stools of the felled oaks have produced regrowth stems of which a considerable number—usually at least one per stool—are straight and well formed; they are now, after nearly 90 years, on an average about 30 feet high.

According to a description of the Stewartry of Kirkcudbright printed as an appendix to Symson's *Description* 'in the west of the Stewartry there be many woods; the most considerable are the Free Forest, upon the Border with Kyle, Torchreigan Wood, the Wood of Gairless and the Wood of Ruseo'. The Free Forest is marked on Pont's map, and McKerlie, after giving the history of the area, writes (1878): 'even now, amidst rocks and heather, portions of the old woods remain, some stunted and not doing credit to their ancestors but others of good size. Although the district is mountainous, in many parts natural wood must have abounded, and not everywhere in the gnarled stunted form, as some seem to think, but in certain parts noble trees of large dimensions. This is proved by the trunks of immense trees found at the bottom of various rivers and lochs. Loch Trool had at one time, and perhaps still has, a great number of large oak trees lying at the bottom, and very large trunks have from time to time been floated and taken ashore from the Cree. From being so long saturated with peat water, the wood when cut up is described as having the appearance of ebony.' At the head of Loch Trool, along the Gareland Burn, between Buchan and Glenhead, is a small area of woodland which contains some very large (sessile) oaks; this area, now the property of the Forestry Commission, has recently been fenced against stock and, with its rowan, birch, ash, and alder, must be a remnant of the ancient woodlands which surrounded Loch Trool.

Torchreigan Wood is probably another name for the Wood of Cree, or possibly for the northern part of it. 'Torthregan' appears in the first (1682) *Valuation Roll* as belonging to the (3rd) Earl of Galloway.

Garlies Wood lies to the south and west of Garlies Castle and remains part of the Galloway Estate. Timber from Garlies Wood was used in the building of the Midsteeple, Dumfries, in 1707. Part of the wood was felled about 1956.

Rusco stands to the north-west of Gatehouse, in the valley of the Fleet, in an area where there is still some old oak wood.

Going eastwards, Symson refers to a 'wood of great overgrowne oaks' at

Kenmure, 'between Kenmure Castle and the town of New Galloway'. 'The considerable woods', he further states, 'on the West side of the Loch of Kenmore, are Carn Edward Wood and the Forest of Craig Gilbert.' Cairn Edward Wood, which is shown on Pont's map, lay to the west of Loch Ken. The Forestry Commission, whose earliest plantations in the south-west of Scotland were in this area, have, appropriately, given the name of Cairn Edward Forest to the forest of which they form part.

In the 1682 *Valuation Roll* 'Craig Gilbert' in the parish of Kells is given as belonging to John Gordon of Kenmure. McKerlie states that 'the forest of Kraiggilbert, shown by Pont in his map was in this parish [Kells] near to Clatteringshaws'. Land in this area has recently been acquired and planted by the Forestry Commission.

It is surprising that there is no mention of the Wood of Airds, also in Kells parish, which has the appearance of a natural oak wood. The writer (the Rev. John Gillespie) of the account of the parish of Kells in the *First Statistical Account of Scotland* (1792) states that 'there are upwards of 500 acres of natural wood in different spots in this parish, consisting mostly of oak, ash, birch, alder and hazel'. He further says that 'these woods have been mostly cut within these 25 years and the young plants are in a thriving state'.

There might also have been a reference to woodlands in the mid Urr valley and in the parish of Dalry, as it is probable that considerable natural woodlands existed near Earlstoun. It is recorded by McKerlie that in 1691 Charles Hope, the owner of the mines at Leadhills in Lanarkshire, bought for 23,000 marks from Sir Alexander Gordon of Earlstoun the wood growing on Earlstoun. When Professor M. L. Anderson was surveying Galloway in search of good stands of sessile oak, he is said to have found fine specimens, which he took to have been part of an original oak forest, in Dalry parish.

Coming now to Nithsdale, we have the very interesting account of the Presbytery of Penpont which was drawn up by the Rev. Mr. Black, Minister of Closeburn, and transmitted to Sir Robert Sibbald; it would thus date from about 1680. It is printed as an appendix to the 1823 edition of Symson's *Description* and also in Macfarlane's *Geographical Collections*.

There is no doubt that Nithsdale was one of the best-wooded valleys in the south-west of Scotland and there is ample confirmation of this in place-names, old maps, and actual remains of woodland. References to woodlands in Black's account are as follows:

The Barony of Eliock, in the parish of Sanquhar, is 'exceedingly well stored with wood; but now of late, by the cutting down of a great part of it for the lead mines of Hopetown [i.e. Leadhills] in Clydesdale and not parking [enclosing] of it afterwards it is much decayed and probably will decay more if, after the cutting of it, it be not more carefully inclosed for the future.' There is a good account of the Eliock woods by Mr. R. C. Blackwood in *Scottish Forestry*, January 1955.

Regarding the hill of Tynron Doon, in the parish of Tynron, Black writes: 'There has been in ancient times, on all hands [i.e. on all sides] of it, very thick woods and great about that place, which made it the more inaccessible'; and he

mentions the fact that a cottage near by, called Cairney croft, was 'incompassed by thick woods'. One has only to look at this ground and its vegetation, as it exists at present, to confirm that Black's statements are correct.

The parish of Keir is said to be 'richly stored with wood' and this is supported by the Rev. Peter Rae in his account of the parish, compiled about 1747. 'This parish', he writes, 'is adorned with excellent woods of oak and some ash and birch. One is Capenoch Bank, betwixt that house and Shinnel Water, most of it oak, which was sold by James Grierson of Capenoch to the miners of Wanlockhead in the year 1710 and was cut down a few years afterwards; and, being enclosed again, is becoming a beautiful young wood: since which time all the other woods in the Keir where I have seen many oaks, both gross and tall, have been sold and cut down and a fine young wood is rising in their room . . . but Nether Barndenoch Bank, sold to the miners at Leadhills, not being enclosed, is lost.' In Pont's *Atlas of Scotland* the only wood shown in the map of Nithsdale is 'the Keyr Wood' in the centre of the parish, to the north of Barjarg. This wood was was still in existence in 1763, being shown on a map of this date in the possession of the present writer. Keir Wood is one of the two Nithsdale woods marked on Kitchin's map of 1769: the subsequent history of the wood is not known, but it is probable that, as time went on, more and more stock grazed in it, making regeneration impossible, and that fellings took place. Many oaks, some of large size, on the farms of Porterstown and Beuchan, attest to the presence of an oak wood in the past. It is likely that other natural woods were 'lost' owing to failure to fence after cutting, as cattle and sheep grazing would prevent any effective regeneration. This point is stressed by Mr. T. C. Smout (1960) in *Scottish Forestry*.

The other Nithsdale wood marked on Kitchin's map is the Holy Wood, in the parish of that name, a few miles north of Dumfries. Old oaks which stand on the side of the main Dumfries–Kilmarnock road near Newtonrigg may be relics of this forest.

Capenoch Bank, referred to above, is now known as Longbank and is so marked on the 1763 map of Keir parish. It is still an oak wood, of good enough quality to win a prize at a recent (1960) Highland Society Forestry competition and one of the present writer's most treasured possessions.

In the parish of Closeburn 'about the place of Closeburn and in other parts of the Barony' was 'some store of oak wood'.

There was also a large area of natural woodland in the valley of the Nith between Enterkinfoot and Carronbridge and in the country surrounding Drumlanrig Castle. Much felling, particularly of oak, was done in the period 1778 to 1810 when the Drumlanrig Estate was owned by 'Old Q', the 4th Duke of Queensberry (b. 1725, d. 1810), the last of the Douglas Dukes. Thomas Pennant, who travelled through the Nith valley in the time of the 4th Duke's predecessor in 1772, noticed the woods but makes no mention of felling. Henry Skrine of Warleigh, however, who visited Drumlanrig in 1787, wrote: '. . . great forests of oak, already, alas, falling beneath the relentless axe, which has dismantled the groves of Drumlanrig.' A poem, the authorship of which has been attributed to Robert Burns and Henry Mackenzie, entitled 'On the Destruction of Drumlanrig Woods' was first pub-

lished in the *Scots Magazine* for July 1803. According to this, before the felling, 'hanging beech', 'spreading elm', and 'stately oaks' adorned the banks of the river Nith near Drumlanrig: afterwards 'scarce a stinted birk [stunted birch] was left'.

There are a number of interesting references to woods in the (unpublished) *Chronologie, Genealogie and Biography of Maitland of Eccles*. Eccles was a small estate, in the parish of Penpont, which had belonged, from early times, to a branch of the family of Maitland of Lethington until its sale, in 1882, by Mrs. Brooke, the only child and heiress of Lauderdale Maitland of Eccles (b. 1809, d. 1881), to her neighbour the 5th Duke of Buccleuch and Queensberry (b. 1806, d. 1884). Eccles lies in an area in which there is evidence that natural woodlands have been in existence for many years.

In 1676 John Maitland of Eccles 'sold his wood to the use of the miners at Leadhills'; this outlet for timber has already been noticed. John Maitland died in the following year and in 1679 his son George 'had a dyke to build about the wood for fencing of the young growth of the wood, it being new cut'; it is interesting to note that the sale of the oak bark 'did more than defray the charge of building this dyke'. The sale of the wood was an important affair, for most of the money which John Maitland left at his death had been derived from the sale of timber.

George Maitland was succeeded at Eccles by his nephew Charles, who was a doctor in Glasgow; in 1719 Dr. Maitland was 'designing to sell his wood [presumably a different wood from that sold by his grandfather] and there were several seeking to buy it; which obliged him to come from Glasgow to the countrey upon 1st May 1719 with his family'. However, the buyers of the wood 'had an eye unto another wood which they thought to buy cheaper, which hindered them to buy the doctor's wood'. There is no record of a sale having taken place and Eccles is still surrounded by oak woods which may well contain trees which the doctor 'designed to sell'.

It will not be inappropriate, I think, to notice two further references to oak woods and to the use of oak timber for building at this period. The first is from the Rae MSS. (*c.* 1747) in the account of the woods in the parish of Tynron. Drumlanrig Castle was being built from 1679 to 1689 and the Clerk of Works was a Mr. Luckup. The latter told Rae that 'when the house was building Sir Robert Grierson of Lag [the owner of Craignee Wood] gifted to Queensberry [his brother-in-law, William Douglas, 3rd Earl and 1st Duke of Queensberry, b. 1637, d. 1695] eleven score of tall stately oaks out of Craignee Wood for joists to the said house and could spare a good cut off the thick end of them'. C. T. Ramage, writing in 1876, records that these joists were only 'replaced a few years ago'. Craignee Wood would be among the woods referred to by Black as surrounding Tynron Doon; the wood, which still survives, lies to the east and south of the hill and, sheltered as it is from the west and north, is just the place where one would expect oaks to grow to a good height. The wood formed part of the Barony of Airds which was acquired from the Griersons of Lag at the beginning of the eighteenth century by the Dukes of Queensberry, in the ownership of whose successors, Buccleuch Estates Ltd., it remains.

The other reference is to McDowall's *History of Dumfries* (1867) in which there

is an account of the building of the Midsteeple in 1707. For this work (oak) 'trees of sufficient size were found at Garlies Wood in the Stewartry'. It is interesting to note that the method of transporting the timber from Garlies to Dumfries was first by horses 'over wretched roads to the Dee; and thence in a flat boat or gabbart and in rafts down Kirkcudbright Bay into the Solway, and thence up the Nith to Kelton or the Dock, where horse power was again needed to take them [*sic*] to Dumfries'. This timber is still to be seen and is in good condition: long may it continue to prove the soundness of the products of our ancient oak woods.

From the above it will be seen that the two main recorded uses of home-grown timber in the south-west of Scotland in the late seventeenth century were for building purposes and for the lead mines of Leadhills or Hopetown (Lanarkshire) and Wanlockhead (Dumfriesshire). The actual buyers of mining timber are variously given: the purchaser at Earlstoun (*c.* 1691) was the owner of the Leadhills mines; the buyers of Capenoch and Nether Barndenoch Banks (*c.* 1710) seem to have been the miners themselves, or possibly contractors acting on their behalf; while in the case of Eccles (1719) a timber merchant appears to have been involved. A large amount of timber must also have been used for firewood and for the making of agricultural implements.

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STUDIES ON *ULMUS*

V. *The Village Elms of Bedfordshire*

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SUMMARY

This biometrical study of the leaves of the village elms of Bedfordshire continues the series of county surveys published in this journal. The number of samples collected was 173. The majority of samples are assigned to two groups of *U. carpinifolia*, three of *U. procera*, one of *U. glabra*, and one representing the Dutch elm. A heterogeneous assortment of forms of *U. carpinifolia* and hybrids between this species and *U. glabra* from the central region of the county is believed to be of comparatively recent introduction. *U. glabra* is indigenous; *U. procera* may be of Roman origin and one of the groups of *U. carpinifolia* an early introduction from Huntingdonshire. The composition of the Bedfordshire elm fauna is also discussed.

A RAPID drive through Bedfordshire does not suggest an elm flora of particular interest. However, a methodical survey of the entire county has shown that the Bedfordshire elm flora is at least as varied as those of Cambridgeshire, Hertfordshire, and Huntingdonshire (cf. Richens, 1958, 1959, 1961). Also, the existence of elms in Bedfordshire in earlier times is comparatively well documented, much of the evidence being conveniently accessible at the County Record Office. An additional feature of the present paper is a consideration of the composition of the Bedfordshire elm fauna.

AREA OF SURVEY

The country covered by the present study is the ancient county of Bedfordshire, including Caddington, Everton, and Studham, partly in other counties, and Swineshead, an enclave of Huntingdonshire.

Physiographically, Bedfordshire comprises a number of contrasting regions. The Chiltern hills, of which the underlying rock is chalk, run diagonally from south-west to north-east across the extreme south of the county. At the foot of these is a belt of low-lying land, largely gault clay, which hereafter will be termed the Vale. To the north of this, and roughly parallel to the Chilterns, is a ridge capped by greensand broken into two sections by the Ivel valley. This feature will be termed the Central Ridge. The Ivel, which runs approximately south to north, joins the Great Ouse at the point where the latter turns sharply westward. The section of the Ouse between this junction and Bedford will be referred to as the Middle Ouse. West of Bedford the Ouse pursues a tortuous course in the north-western area of the county, where its meanders have cut down through the overlying clays to Jurassic limestone. This stretch will be referred to as the Upper Ouse. The north-east of the county is a clay plateau, largely boulder clay.

As in previous studies, the elms were sampled as far as possible from the old closes around the village centres of each ancient parish.

BIOMETRIC PROCEDURE

The same eight quantitative foliar characters used in previous studies are utilized here, namely: absolute length of the longer side of the lamina; lamina breadth/lamina length; petiole length/lamina length; the degree of basal asymmetry; the absolute number of teeth; and the breadth, length, and depth of the primary teeth. As before, five subdistal leaves from dwarf shoots on large branches are measured from each tree sampled.

The mean measurements of all the samples collected are presented in Table I. As in previous studies, the measurements for each character are reduced to the same 10-unit scale (0–9) as used previously, though this has been transcended in a number of instances. The characters are cited in the order set out below, an asterisk being added when the leaves are scabrous.

The range and size of the scaled unit for each character are:

Length . . .	3–8 cm.,	1 unit being	0·5 cm.
Relative breadth .	0·40–0·90	,, ,,	0.05
Relative petiole length	0·00–0·20	,, ,,	0·02
Basal asymmetry .	0·00–0·20	,, ,,	0·02
Tooth number . .	50–150	,, ,,	10
Tooth breadth . .	3–8 mm.	,, ,,	0·5 mm.
Tooth length . .	3–8 mm.	,, ,,	0·5 mm.
Tooth depth . .	0–5 mm.	,, ,,	0·5 mm.

The method used in analysing the data is that described in the previous paper of this series. Maps, Fig. 2, are constructed in which all samples in direct taxonomic-geographic (*TG*) continuity are joined by bars. As before, the interval of comparison is taken as 1 scaled unit (approximately 0·1 of the range). The groups revealed by mapping in this way provide the basis for the recognition of taxonomic groups (written in capitals), which are defined, as previously, in terms of the lower and upper limits of each quantitative character.

Representative leaves of the entire collection are illustrated in Fig. 1. The taxonomic groups are defined in Table II. In Fig. 3.1 the areas in which elms are frequent are shown. It will be noted that elms are infrequent in much of the northern clay plateau, in the central ridge, the villages near the junction of the Ouse and Ivel, and in the Chilterns. No samples were collected at Chellington, Clapham, Dunstable, Flitwick, Sandy, Studham, or Thurleigh.

The areas of distribution of the taxonomic groups recognized are also shown in Fig. 3.

TAXONOMIC ANALYSIS

Most of the samples collected can be unequivocally assigned to one or other of the species *U. carpinifolia* Gled. sensu Rehder, *U. procera* Salisb., or *U. glabra* Huds.

U. carpinifolia is principally encountered in the villages in the north of the county. Along the Huntingdonshire border, *U. carpinifolia* frequently occurs to the exclusion of all other species. The samples fall into two groups, designated the DEAN and CARLTON groups, the former mainly found along the Huntingdonshire

TABLE I. *Mean scaled values for* (1) *length*, (2) *relative breadth*, (3) *relative petiole length*, (4) *basal asymmetry*, (5) *tooth number*, (6) *tooth breadth*, (7) *tooth length, and* (8) *tooth depth*

Parish		*Grid reference*	*Biometrical values*
Ampthill	*a*	52/03	7 . 2 5 3 . (13) . 0 1 3
	b		5 . 8 4 6 . 3 . 6 5 7*
Arlesey		52/13	4 . 8 5 4 . 3 . 6 5 6*
Aspley Guise	*a*	42/93	6 . 3 6 5 . 7 . 2 3 4
	b		5 . 7 3 3 . 4 . 4 4 5*
Astwick		52/23	5 . 8 4 5 . 3 . 7 6 6*
Barton in the Clay		52/03	4 . 7 5 4 . 2 . 5 5 6*
Battlesden		42/92	5 . 7 4 6 . 2 . 4 4 6*
Bedford (several Parishes)		52/04	5 . 8 4 5 . 4 . 4 4 5*
Biddenham		52/04	5 . 8 5 6 . 2 . 5 5 6*
Biggleswade	*a*	52/14	4 . 2 5 2 . 3 . 1 2 3
	b		4 . 8 5 7 . 4 . 5 4 6*
Birchmoor	*a*	42/93	(10) . 3 2 4 . 9 . 3 4 4
	b		5 . 7 3 4 . 1 . 6 6 7*
	c		(13) . 3 1 4 . (15) . 3 3 5*
Bletsoe	*a*	52/05	6 . 2 3 1 . 2 . 4 4 4
	b		5 . 8 4 5 . 2 . 6 5 6*
Blunham		52/15	5 . 7 5 4 . 4 . 4 3 5*
Bolnhurst	*a*	52/05	4 . 7 3 4 . 2 . 6 5 6*
	b		(−1) . 9 9 4 . (−1) . 2 2 4
	c		1 . 8 7 6 . 1 . 3 2 5
Bromham	*a*	52/05	7 . 2 5 3 . 9 . 3 3 4
	b		5 . 8 4 5 . 2 . 6 5 6*
Caddington		52/01	5 . 8 4 6 . 1 . 4 4 6*
Campton	*a*	52/13	9 . 5 7 5 . 7 . 5 9 (10)
	b		4 . 7 5 5 . 4 . 5 5 5*
	c		(10) . 4 2 3 . (10) . 3 2 4*
Cardington		52/04	4 . 7 6 7 . 3 . 4 4 5*
Carlton	*a*	42/95	8 . 1 7 4 . 6 . 4 4 4
	b		5 . 6 3 5 . 2 . 6 6 6*
Chalgrave		52/02	5 . 7 3 4 . 1 . 6 7 7*
Chellington		42/95	
Clapham		52/05	
Clifton		52/13	4 . 7 8 8 . 5 . 4 3 6*
Clophill	*a*	52/03	7 . 2 3 1 . 5 . 4 4 5
	b		5 . 7 4 5 . 2 . 6 5 6*
Cockayne Hatley		52/24	6 . 6 5 6 . 4 . 6 5 6*
Colmworth	*a*	52/15	7 . 3 5 2 . 5 . 4 4 5
	b		4 . 8 5 6 . 3 . 6 5 6*
Cople	*a*	52/14	5 . 4 6 4 . 5 . 4 4 5
	b		5 . 7 4 4 . 3 . 5 4 6*
Cranfield	*a*	42/94	5 . 2 4 3 . 5 . 2 2 4
	b		7 . 2 3 4 . 8 . 1 2 3
	c		5 . 7 5 5 . 4 . 5 5 6*
Dean		52/06	5 . 2 6 2 . 6 . 2 3 4
Dunstable		52/02	

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	b		5 . 7 3 3 . 4 . 4 4 5*
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Battlesden		42/92	5 . 7 4 6 . 2 . 4 4 6*
Bedford (several Parishes)		52/04	5 . 8 4 5 . 4 . 4 4 5*
Biddenham		52/04	5 . 8 5 6 . 2 . 5 5 6*
Biggleswade	*a*	52/14	4 . 2 5 2 . 3 . 1 2 3
	b		4 . 8 5 7 . 4 . 5 4 6*
Birchmoor	*a*	42/93	(10) . 3 2 4 . 9 . 3 4 4
	b		5 . 7 3 4 . 1 . 6 6 7*
	c		(13) . 3 1 4 . (15) . 3 3 5*
Bletsoe	*a*	52/05	6 . 2 3 1 . 2 . 4 4 4
	b		5 . 8 4 5 . 2 . 6 5 6*
Blunham		52/15	5 . 7 5 4 . 4 . 4 3 5*
Bolnhurst	*a*	52/05	4 . 7 3 4 . 2 . 6 5 6*
	b		(−1) . 9 9 4 . (−1) . 2 2 4
	c		1 . 8 7 6 . 1 . 3 2 5
Bromham	*a*	52/05	7 . 2 5 3 . 9 . 3 3 4
	b		5 . 8 4 5 . 2 . 6 5 6*
Caddington		52/01	5 . 8 4 6 . 1 . 4 4 6*
Campton	*a*	52/13	9 . 5 7 5 . 7 . 5 9 (10)
	b		4 . 7 5 5 . 4 . 5 5 5*
	c		(10) . 4 2 3 . (10) . 3 2 4*
Cardington		52/04	4 . 7 6 7 . 3 . 4 4 5*
Carlton	*a*	42/95	8 . 1 7 4 . 6 . 4 4 4
	b		5 . 6 3 5 . 2 . 6 6 6*
Chalgrave		52/02	5 . 7 3 4 . 1 . 6 7 7*
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Clifton		52/13	4 . 7 8 8 . 5 . 4 3 6*
Clophill	*a*	52/03	7 . 2 3 1 . 5 . 4 4 5
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Cople	*a*	52/14	5 . 4 6 4 . 5 . 4 4 5
	b		5 . 7 4 4 . 3 . 5 4 6*
Cranfield	*a*	42/94	5 . 2 4 3 . 5 . 2 2 4
	b		7 . 2 3 4 . 8 . 1 2 3
	c		5 . 7 5 5 . 4 . 5 5 6*
Dean		52/06	5 . 2 6 2 . 6 . 2 3 4
Dunstable		52/02	

TABLE I (*cont.*)

Parish		*Grid reference*	*Biometrical values*
Dunton	*a*	52/24	1 . 3 6 2 . 1 . 1 1 3
	b		5 . 7 4 5 . 3 . 6 5 7*
Eaton Bray		42/92	4 . 9 5 7 . 2 . 7 6 7*
Eaton Socon	*a*	52/15	7 . 1 8 4 . 6 . 4 5 5
	b		5 . 8 5 4 . 4 . 5 5 5*
Edworth		52/24	4 . 8 4 3 . 3 . 6 5 6*
Elstow		52/04	5 . 6 4 4 . 3 . 4 4 5*
Eversholt		42/93	5 . 7 5 5 . 2 . 5 5 6*
Everton		52/25	4 . 9 4 7 . 3 . 6 5 7
Eyworth	*a*	52/24	3 . 5 4 3 . 4 . 3 3 5*
	b		6 . 6 4 5 . 3 . 6 6 6*
Farndish	*a*	42/96	8 . 2 6 4 . 5 . 5 6 5
	b		5 . 7 3 2 . 2 . 5 5 5*
Felmersham	*a*	42/95	8 . 2 8 4 . 6 . 6 7 5
	b		6 . 3 5 5 . (12) . 2 3 5
	c		5 . 8 5 6 . 4 . 5 5 6*
	d		7 . 5 5 4 . (10) . 4 4 4
Flitton		52/03	5 . 7 4 5 . 3 . 6 6 7*
Flitwick		52/03	
Goldington		52/05	4 . 8 5 5 . 3 . 4 4 6*
Gravenhurst	*a*	52/13	7 . 5 3 3 . 9 . 4 4 5
	b		5 . 6 5 5 . 2 . 5 5 5*
Great Barford		52/15	5 . 7 5 7 . 3 . 5 4 6*
Harlington		52/03	5 . 6 4 4 . 2 . 6 5 6*
Harrold	*a*	42/95	6 . 2 (10) 5 . 3 . 3 4 5
	b		5 . 8 4 4 . 2 . 5 5 6*
Haynes		52/04	4 . 6 5 4 . 3 . 3 3 4*
Henlow		52/13	5 . 8 5 5 . 3 . 5 5 6*
Higham Gobion		52/13	4 . 6 4 6 . 2 . 4 4 5*
Hockliffe	*a*	42/92	(11) . 3 4 5 . (11) . 5 5 5
	b		5 . 7 4 3 . 3 . 4 4 6*
Holcot	*a*	42/93	5 . 7 3 4 . 2 . 5 5 6*
	b		(11) . 4 2 2 . 9 . 3 3 5*
Holwell		52/13	5 . 6 4 4 . 3 . 5 4 6*
Houghton Conquest	*a*	52/04	5 . 5 4 3 . 5 . 3 4 4
	b		(10) . 5 3 4 . (11) . 5 5 5
	c		5 . 8 5 6 . 4 . 5 5 5*
Houghton Regis		52/02	5 . 8 4 5 . 3 . 3 3 5*
Husborne Crawley	*a*	42/93	5 . 7 4 6 . 3 . 4 4 6*
	b		(10) . 3 2 4 . (10) . 2 2 4*
Kempton		52/04	5 . 7 4 5 . 3 . 5 5 6*
Keysoe	*a*	52/06	4 . 2 5 3 . 4 . 1 1 3
	b		4 . 8 4 4 . 1 . 5 4 5*
Knotting	*a*	52/06	3 . 4 7 3 . 4 . 1 1 4
	b		4 . 7 5 4 . 1 . 4 4 5*
Langford		52/14	5 . 8 5 7 . 4 . 5 4 6*
Leighton Buzzard		42/92	4 . 7 4 5 . 2 . 4 4 5*
Lidlington		42/93	4 . 7 4 3 . 1 . 4 4 6*

TABLE I (*cont.*)

Parish		*Grid reference*	*Biometrical values*
Little Barford	*a*	52/15	5 . 7 5 6 . 3 . 5 4 5*
	b		5 . 6 6 3 . 8 . 4 4 4
Little Staughton		52/06	4 . 3 7 2 . 5 . 2 3 4
Luton		52/02	5 . 6 4 4 . 2 . 4 4 5*
Marston Moretaine	*a*	42/94	9 . 5 4 4 . 9 . 5 5 5
	b		4 . 7 5 5 . 4 . 3 3 5*
Maulden	*a*	52/03	9 . 5 3 5 . 6 . 5 5 5
	b		5 . 7 4 5 . 2 . 5 5 6*
Melchbourne		52/06	6 . 2 6 2 . 6 . 3 3 4
Meppershall		52/13	4 . 8 4 5 . 4 . 3 3 5*
Millbrook	*a*	52/03	8 . 5 3 4 . 7 . 5 5 5
	b		5 . 7 3 5 . 2 . 6 7 7*
	c		11 . 3 2 5 . 13 . 2 2 3*
Milton Bryan		42/93	5 . 8 2 3 . 2 . 6 5 7*
Milton Ernest	*a*	52/05	10 . 4 3 5 . 5 . 4 3 4*
	b		5 . 7 4 4 . 2 . 5 4 6*
	c		6 . 2 5 4 . 7 . 3 4 5*
Northill	*a*	52/14	4 . 3 7 3 . 8 . 2 3 4
	b		5 . 8 4 7 . 4 . 6 4 6*
Oakley		52/05	6 . 7 3 3 . 3 . 4 4 5*
Odell		42/95	6 . 2 7 4 . . 3 . 4 5 5
Pavenham	*a*	42/95	6 . 5 7 3 . 5 . 4 4 5
	b		5 . 7 3 4 . 2 . 5 5 6*
	c		7 . 4 4 2 . 5 . 3 3 5*
Pertenhall	*a*	52/06	4 . 3 5 2 . 2 . 4 4 4
	b		5 . 7 5 5 . 4 . 4 4 5*
Podington	*a*	42/96	7 . 1 6 4 . 4 . 4 4 5
	b		4 . 8 4 4 . 4 . 6 6 7*
Potsgrove		42/92	4 . 7 4 4 . 3 . 5 5 6*
Potton		52/24	5 . 8 5 6 . 4 . 4 4 5*
Pulloxhill		52/03	5 . 6 5 6 . 3 . 5 5 5*
Ravensden		52/05	4 . 8 4 5 . 2 . 5 4 6*
Renhold		52/05	5 . 7 4 4 . 3 . 6 5 6*
Ridgmont		42/93	5 . 6 5 5 . 4 . 3 3 4*
Riseley	*a*	52/06	7 . 3 5 3 . 4 . 3 3 5
	b		4 . 7 5 5 . 3 . 6 5 7*
Roxton		52/15	8 . 6 6 5 . 7 . 7 6 5
Salford	*a*	42/93	6 . 4 5 5 . (11) . 2 3 5
	b		4 . 4 4 2 . 2 . 4 4 4
	c		9 . 6 4 5 . 12 . 5 5 5
	d		4 . 8 5 6 . 2 . 5 5 6*
Sandy		52/14	
Sharnbrook	*a*	42/95	5 . 8 4 2 . 2 . 6 6 7*
	b		9 . 5 2 4 . 9 . 3 3 5*
Shelton		52/06	5 . 2 6 3 . 5 . 2 3 4
Shillington		52/13	5 . 7 7 7 . 3 . 4 3 5*
Souldrop		42/96	6 . 2 8 3 . 2 . 5 5 4
Southill		52/14	5 . 7 5 5 . 3 . 5 5 6*
Stagsden		42/94	5 . 8 4 3 . 2 . 5 5 6*

TABLE I (*cont.*)

Parish		Grid reference	Biometrical values									
Steppingley		52/03	4	7	4	3	1	5	5	6*
Stevington	*a*	42/95	7	2	(11)	6	5	4	5	5
	b		5	7	4	5	2	6	6	7*
Stondon		52/13	4	7	4	5	3	3	3	5*
Stotfold		52/23	6	6	4	5	3	6	5	6*
Streatley		52/02	5	6	5	5	2	5	5	5*
Studham		52/01								
Sundon		52/02	5	6	5	5	2	4	4	6*
Sutton	*a*	52/24	3	2	7	1	4	1	2	3
	b		5	8	5	7	4	6	5	5*
Swineshead		52/06	4	3	7	4	7	2	2	4
Tempsford		52/15	5	6	4	5	3	5	4	5*
Thurleigh		52/05								
Tilbrook		52/06	5	2	7	3	5	2	3	4
Tilsworth		42/92	4	7	4	2	1	4	4	5*
Tingrith		52/03	5	7	7	7	3	4	4	5*
Toddington		52/02	5	7	3	3	1	6	6	7*
Totternhoe		42/92	4	7	4	6	3	3	3	4*
Turvey	*a*	42/95	8	2	7	4	5	4	5	5
	b		5	8	4	5	3	6	5	7*
Warden	*a*	52/14	4	4	9	2	3	4	5	5
	b		4	7	5	6	2	5	4	6*
Westoning		52/03	4	6	4	4	1	5	5	6*
Whipsnade		52/01	4	7	6	6	3	4	4	6*
Wilden		52/05	5	7	4	5	3	5	4	6*
Willington		52/14	4	8	4	5	3	6	5	6*
Wilstead	*a*	52/04	7	3	6	3	5	3	2	4
	b		5	6	5	4	4	3	3	4*
	c		(10)	3	3	5	(10)	2	2	4*
Woburn	*a*	42/93	4	5	3	1	4	1	1	4
	b		4	7	4	5	4	4	4	5*
	c		9	6	3	4	(12)	2	3	5*
Wootton		52/04	5	8	6	5	3	5	5	5*
Wrestlingworth		52/24	5	7	5	6	5	7	7	7*
Wymington		42/96	7	3	6	2	3	6	7	6*
Yelden	*a*	52/06	6	1	7	4	3	3	4	4
	b		4	7	3	4	2	5	5	6*

border and the latter in a zone to the immediate south of this and along the Upper Ouse. The distinction between the two groups is based on two characters, leaf length and tooth size, both of which have higher values in the CARLTON group.

The DEAN group comprises the following samples:

Biggleswade[a], Dean (Fig. 1.1), Keysoe[a], Little Staughton, Shelton, Sutton[a], Swineshead, and Tilbrook. The Pertenhall[a] and depauperate Dunton[a] (Fig. 1.2) samples are similar. Several samples, Bromham[a], Harrold[a] (Fig. 1.3), Melchbourne, Milton Ernest[c], Riseley[a] (Fig. 1.4), and Yelden[a], combine the small teeth of the DEAN elms with the longer leaves of the CARLTON group.

The samples comprising the CARLTON group are:

Carlton[a] (Fig. 1.5), Colmworth[a], Eaton Socon[a], Farndish[a], Felmersham[a], Odell, Podington[a], Souldrop, Stevington[a], Turvey, and Wymington.

The most frequent species in the county is *U. procera*, which is found everywhere except the extreme north but is most frequent in the Vale and by the western Middle Ouse. Most of the samples of this species are in *TG*-continuity *inter se* and are also in *TG*-continuity with samples collected previously in Hertfordshire and Huntingdonshire. However it is convenient to divide this population into three, designated the BEDFORD, LUTON, and BIGGLESWADE groups.

The BEDFORD group is the largest and most widely distributed. It comprises the following samples: Ampthill[b], Arlesey, Barton in the Clay, Battlesden, Bedford (Fig. 1.6), Biddenham, Bletsoe[b], Blunham, Bolnhurst[a], Bromham[b], Campton[b], Clophill[b], Colmworth[b], Cople[b], Cranfield[c], Dunton[b], Eaton Socon[b], Eversholt, Felmersham[c], Flitton, Goldington, Harrold[b], Henlow, Holcot[a], Houghton Conquest[c], Houghton Regis, Husborne Crawley[a], Kempton, Leighton Buzzard, Little Barford[a], Marston Moretaine[b], Maulden[b], Meppershall, Milton Ernest[b], Pavenham[b], Pertenhall[b], Podington[b], Potsgrove, Potton, Ravensden, Renhold, Riseley[b], Salford[d], Southill, Stevington[b], Stondon, Turvey[b], Warden[b], Wilden, Willington, Woburn[b], and Yelden[b].

The leaves are very broad and asymmetry is moderate.

TABLE II. *Principal populations and their biometrical ranges*

Group	*Biometrical range*								
U. carpinifolia									
DEAN	4–5	2–3	5–7	2–4	3–7	1–3	1–3	3–4	
CARLTON	6–8	1–3	5–11	2–6	2–7	4–6	4–7	4–6	
U. procera									
BEDFORD	4–5	7–8	3–5	4–6	2–4	3–6	3–6	5–7*	
LUTON	4–5	6	4–5	4–6	1–3	4–6	4–5	5–6*	
BIGGLESWADE	4–5	7–9	4–5	7	3–4	5–6	4–5	5–7*	
U. glabra	9–(13)	3–6	1–3	2–5	9–(15)	2–3	2–3	3–5*	
Dutch elm	7–(10)	5–6	3–6	3–5	6–(12)	4–7	4–6	4–5	

A considerable number of samples differ from typical BEDFORD elms in their shorter petiole or less marked asymmetry. These resemble the ST. ALBANS group of Hertfordshire, characterized by low values for both these characters. In Bedfordshire, however, elms of this type are scattered and they have therefore not been assigned to a group of their own. Samples of this sort comprise: Aspley Guise[b], Birchmoor[b], Chalgrave, Edworth, Farndish[b], Hockliffe[b], Lidlington, Millbrook[b], Milton Bryan (Fig. 1.7), Oakley, Sharnbrook[a], Stagsden, Steppingley, Tilsworth, and Toddington.

Other elms closely related to the BEDFORD group include: Astwick, Caddington (previously included in the HITCHIN group of Hertfordshire elms), Keysoe[b], Knotting[b], Totternhoe, Whipsnade, Wootton, and Wrestlingworth.

Two highly aberrant samples, presumably derived from this group, were collected at Bolnhurst, Bolnhurst[b] (Fig. 1.8), and Bolnhurst[c]. These have extremely

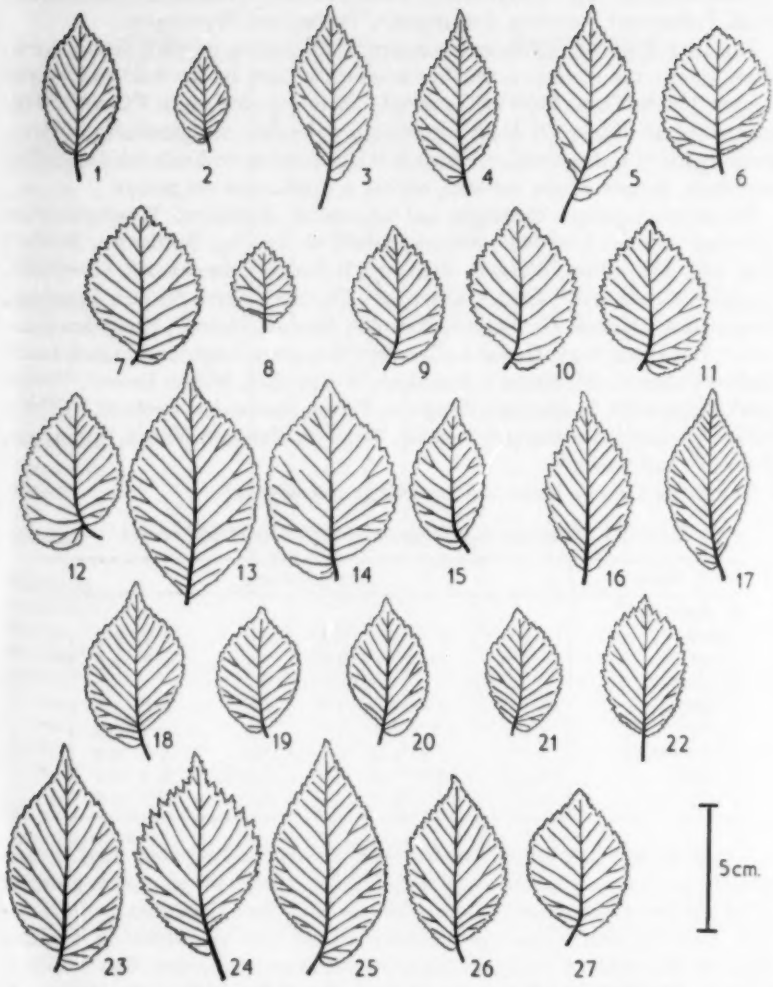

FIG. 1. Specimen elm leaves. 1, Dean (DEAN); 2, Dunton[a]; 3, Harrold[a]; 4, Riseley[a]; 5, Carlton[a] (CARLTON); 6, Bedford (BEDFORD); 7, Milton Bryan; 8, Bolnhurst[b]; 9, Luton (LUTON); 10, Eyworth[b]; 11, Biggleswade (BIGGLESWADE); 12, Clifton; 13, Holcot[b]; 14, Maulden[a]; 15, Cranfield[a]; 16, Clophill[a]; 17, Ampthill[a]; 18, Salford;[a] 19, Woburn[a]; 20, Cople[a]; 21, Eyworth[a]; 22, Warden[a]; 23, Birchmoor[a]; 24, Campton[a]; 25, Hockliffe[a]; 26, Pavenham[c]; 27, Little Barford[b].

small smooth leaves with few teeth and relatively long petioles. It is possible that these samples are infected by a virus and that their distinctive appearance at two levels of expression is due to different degrees of infection. In clonally propagated species such as *U. procera* and *U. carpinifolia*, viruses could be widespread and contribute appreciably to clonal variation. Heybroek (personal communication) has suggested this possibility with regard to the distinctive characteristics of the BRAUGHING group of *U. carpinifolia* in Hertfordshire.

The second group of *U. procera* is the LUTON population. This is mainly found in a group of parishes in the vicinity of Luton. The samples are: Elstow, Gravenhurst[b], Harlington, Higham Gobion, Holwell, Luton (Fig. 1.9), Pulloxhill, Streatley, Sundon, Tempsford, and Westoning. Similar elms also occur in nearby parts of Hertfordshire.

The characteristic feature of this group, compared with the BEDFORD group, is the narrower leaf.

Other samples with the narrower leaf characteristic of this group are: Carlton[b], Cockayne Hatley, Eyworth[b] (Fig. 1.10), Ridgmont, Stotfold, and Wilstead[b].

The third group of *U. procera* is the smallest and is restricted to the vicinity of Biggleswade, after which it is named. The samples assigned to the BIGGLESWADE group are: Biggleswade[b], Everton, Great Barford, Langford, Northill[b], and Sutton[b]. The feature demarcating these elms from the BEDFORD group is the high value for asymmetry, a feature also shared by the Eaton Bray elm. Four other elms, the Cardington, Clifton (Fig. 1.12), Shillington, and Tingrith samples, are similar to the BIGGLESWADE group but have longer petioles.

Nine samples, Birchmoor[c], Campton[c], Holcot[b], Husborne Crawley[b] (Fig. 1.13), Millbrook[c], Milton Ernest[a], Sharnbrook[b], Wilstead[c], and Woburn[c], are typical specimens of *U. glabra*. They were mostly collected from the Central Ridge. This species is very uniform over its entire European range and the Bedfordshire samples could easily be matched with material of this species from northern England, Scotland, or even Austria. All the species fall within the biometrical range indicated in Table II except Milton Ernest[a], a specimen in poor condition in which the tooth number is abnormally low.

Of all the counties so far investigated, Bedfordshire is the first in which the Dutch Elm makes an appreciable contribution to the landscape. Even here, however, it seldom occurs other than sporadically and is principally found on the Central Ridge. The collections of the Dutch Elm comprise: Felmersham[d], Gravenhurst[a], Houghton Conquest[b], Marston Moretaine[a], Maulden[a] (Fig. 1.14), Millbrook[a], Roxton, and Salford[c].

The distinguishing characteristics of the Dutch Elm are the large, broad, usually glabrous leaves with high tooth numbers. Biometrical discrimination, based only on the foliar characters used here, between the Dutch elm and another horticultural clone, the Huntingdon elm, is sometimes uncertain, but in general the Dutch elm has rather smaller and more asymmetrical leaves than the Huntingdon elm and the teeth are shallower.

There remains a very heterogeneous assemblage of elms, mainly confined to the Central Ridge and the Upper Ouse valley, which are best considered together.

Few of these samples are in *TG*-continuity with any other, and in several cases the samples cannot be matched by any elms in this or the adjoining counties, and in some cases, only by elms from continental Europe.

Some components of this aggregate, however, have small and narrow leaves resembling the DEAN elms, namely the Aspley Guise[a], Cranford[a] (Fig. 1.15), and Northill[a] samples. The Wilstead[a] elm comes into the category of forms intermediate between the DEAN and CARLTON groups.

The Bletsoe[a] and Clophill[a] (Fig. 1.16) elms are narrow-leaved, the teeth being of moderate size, but they are distinguished from the other narrow-leaved samples by their low values for petiole length and asymmetry. Elms closely related to these have not been encountered before.

Two other samples, Ampthill[a] (Fig. 1.17) and Cranfield[b], have no close analogies among the English elms so far investigated. They have long narrow leaves, very small teeth, and very high tooth numbers.

Also with very high tooth numbers, but a rather broader lamina, more pronounced asymmetry, and larger teeth, are the two elms Felmersham[b] and Salford[a] (Fig. 1.18). The elms considered in the preceding four paragraphs could all be confidently assigned to *U. carpinifolia*. The last two samples could also pertain to this species but may also include *U. glabra* in their ancestry.

Among the samples with broader leaves, two, Knotting[a] and Woburn[a] (Fig. 1.19) have small leaves with low asymmetry and very small teeth. This type of *U. carpinifolia* is characteristic of eastern Kent and occurs also in France. Five samples, chiefly differing from the preceding in their larger teeth and in some cases larger overall size, were also found: Cople[a] (Fig. 1.20), Eyworth[a] (Fig. 1.21), Houghton Conquest[a], Pavenham[a], and Salford[b]. This type of elm occurs sporadically in Cambridgeshire, in particular at Guilden and Steeple Morden near the Bedfordshire border, and in Hertfordshire.

The Warden[a] elm (Fig. 1.22), with its moderately broad leaves, very long petiole, and low asymmetry, can be matched by the BRAUGHING elms of north-east Hertfordshire.

Three samples, Birchmoor[a] (Fig. 1.23), Campton[a] (Fig. 1. 24), and Hockliffe[a] (Fig. 1.25), appear to be hybrids between *U. carpinifolia* and *U. glabra*, though none can be assigned to any of the better-known hybrid clones of this parentage. All are smooth-leaved. The Campton[a] elm is a remarkable form with very deeply toothed leaves, rather reminiscent of aspen leaves; a remote affinity to *U. carpinifolia* × *U. glabra* var. *belgica* is conceivable.

Putative F_1 hybrids of *U. carpinifolia* × *U. glabra* are typically smooth-leaved. The rough-leaved Pavenham[c] sample (Fig. 1.26) appears also to be a hybrid of this parentage and might possibly represent an advanced-generation segregate.

The Little Barford[b] elm (Fig. 1.27) poses a final taxonomic problem. While this tree has the general appearance of *U. procera*, the leaves are smooth and differ from those of the *U. procera* groups defined above in their longer petioles, lower asymmetry, higher tooth number, and shallower teeth. The size of the leaf suggests *U. procera* or *U. carpinifolia* as a parent; the relative breadth, *U. procera*, *U. glabra*, or the Dutch elm; the petiole length *U. carpinifolia* or the Dutch elm;

and tooth number *U. glabra* or the Dutch elm. The combinations *U. carpinifolia* × Dutch elm or *U. procera* × Dutch elm could be envisaged as giving rise to such a form. Nothing however seems to have been recorded on the progeny given by the Dutch elm, and whether or not this elm is heterozygous is also uncertain. More information is required before the origin of the Little Barford[6] elm can be elucidated further.

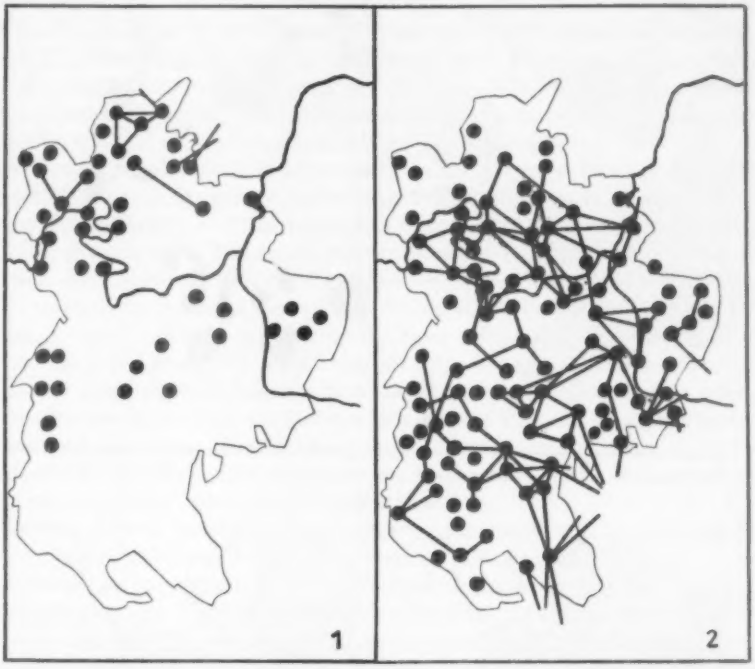

FIG. 2. Maps illustrating samples in *TG*-continuity: 1, *U. carpinifolia*; 2, *U. procera*. All samples in direct *TG*-continuity are connected by bars. The main river is the Ouse; the branch is the Ivel.

The only species of elm for which an indigenous status can be confidently claimed in Bedfordshire is *U. glabra*, which has probably persisted in the county since late Boreal times in woods in the Chilterns, in woods on or near the Central Ridge, and perhaps also in coppices on the limestone outcrops along the Upper Ouse. As will be seen below, there is documentary evidence for its occurrence on the Central Ridge in the fourteenth century. Aubrey, who had a judicious eye for elms, writes that 'Edmund Wyld, Esq. of Houghton Conquest in Bedfordshire, R. S. S. assures me that in Bedfordshire, in several woods, *e.g.* about Wotton, &c. that elme does grow naturally, as ashes, beeches, &c; but quaere, what kind of elm it is?' It is likely, as Aubrey seems to have suspected, that the elm concerned was *U. glabra*.

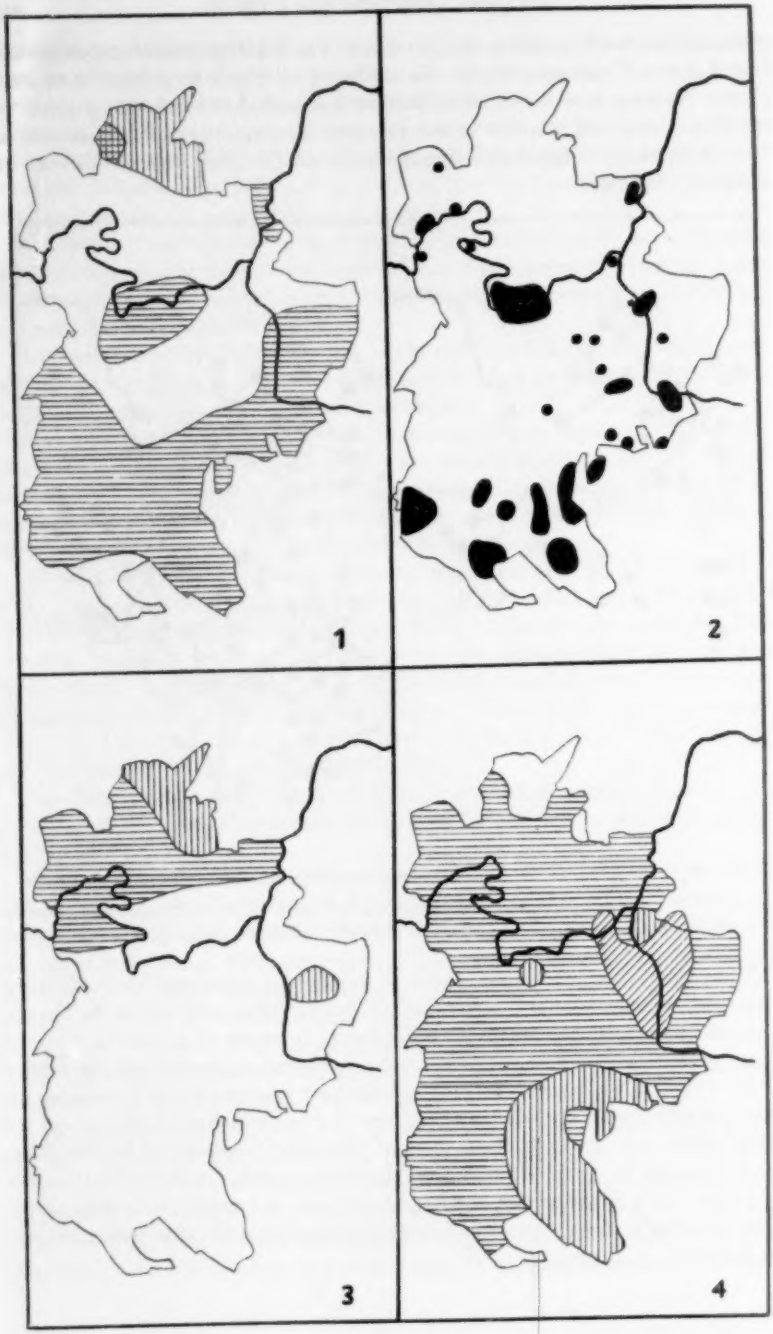

Fig. 3

Dony (1953) mentions a wood composed entirely of *U. glabra* as still existing at Stanbridge in the ancient parish of Leighton Buzzard.

The two groups of *U. carpinifolia* are probably of human introduction. The DEAN group is clearly an offshoot of the GODMANCHESTER elms of Huntingdonshire which also extend into western Cambridgeshire. Were elms alone considered, the northern fringe of Bedfordshire would be interpreted as an appanage of Huntingdonshire. The status of the CARLTON group is less evident. The elms occur in the villages of the Upper Ouse, often intermixed with *U. procera* and sometimes with *U. glabra*; they do not occur in great quantity. This group might possibly have developed from the DEAN group, or it could be of independent origin, possibly from Northamptonshire. Until Northamptonshire has been systematically sampled for elm, it would be unprofitable to discuss this group further.

U. procera, almost certainly of human introduction too, is the most widely distributed species in the county, and it is probable that the BEDFORD group represents the original form of this species, the LUTON and BIGGLESWADE groups being local derivatives of it. The BEDFORD group occurs in four main areas. The most extensive of these is the Vale and the second largest the valley of the Middle Ouse. The third area is restricted to the Yelden[b] elms which probably represent an offshoot of the *U. procera* population of the Nene valley. The fourth area is along the Ouse around Eaton Socon and extends a short distance into Huntingdonshire. There is every reason to suppose that the *U. procera* populations of northern Hertfordshire derive from the BEDFORD group of the Vale and, to a lesser extent, from the LUTON group. The HITCHIN group of *U. procera* (cf. Richens, 1959), the principal Hertfordshire form of the species, is extremely similar biometrically to the BEDFORD group and is in *TG*-continuity with it.

Evidence will be considered later which suggests that the *U. procera* populations of both the Vale and the Middle Ouse are of respectable antiquity.

Less appears to be known about the Dutch elm than about any other commonly grown English elm. There appears to be no reason to doubt the generally received opinion that this elm was introduced from Holland soon after the accession of William III. It is first mentioned by Plukenet (1696), the Queen's Botanist and Superintendent of Hampton Court Garden, and it was being sold in large quantities for training as espaliers in the Dutch style by the Brompton nursery as early as 1699 (cf. Green, 1956). It seems likely that the homogeneous Bedfordshire samples of the Dutch elm all derive from this introduction.

However, there are complications. Although the Dutch elm is believed to occur in Holland, it is rare, and it may have been imported into Holland from elsewhere, for instance Belgium, France, or even England. The last possibility cannot be brushed aside in view of the extraordinary range of large-leaved elms occurring in central Essex, many having the conspicuous corky flanges on the branches

FIG. 3. Distribution maps. 1, areas in which elms are frequent; vertical hatching, *U. carpinifolia*; horizontal hatching, *U. procera*; 2, locations of prehistoric finds (Neolithic, Bronze and Iron Ages), redrawn, with permission, from Thomas (1956); 3, *U. carpinifolia* groups: vertical hatching, DEAN group; horizontal hatching, CARLTON group; 4, *U. procera* groups: horizontal hatching, BEDFORD group; vertical hatching, LUTON group; diagonal hatching, BIGGLESWADE group. Rivers as in Fig. 2.

characteristic of the Dutch elm, but frequently differing quite markedly in leaf characters from the standard Dutch elm. These large-leaved Essex elms are very abundant locally, and while it may be that the Dutch and Essex populations arose independently, quite feasibly from interspecific hybridization between *U. carpinifolia* and *U. glabra*, the possibility of importation of elm at an earlier date from Essex to Holland might be worth investigating.

The heterogeneous samples of *U. carpinifolia* from the Central Ridge and Upper Ouse would most easily be accounted for on the assumption of comparatively recent planting in the eighteenth and nineteenth centuries. Many exotic tree species have been planted in these areas, largely inspired, no doubt, by the timber-planting activities of the Dukes of Bedford, and it seems likely that elms were among the species introduced. In some cases, the elms appear to be of foreign origin, probably French, and this would accord with Elwes and Henry's (1913) statement that elm seed of *U. carpinifolia* has long been imported into this country from France.

The putative hybrids between *U. carpinifolia* and *U. glabra* may have arisen locally, or perhaps represent hybrids that originated elsewhere; quite likely both explanations apply.

Only one detailed account of the Bedfordshire elm flora has been published previously, that by Dony (1953) in his Bedfordshire flora, based largely on identifications by R. Melville. There are various difficulties in the way of comparing this and the present treatment, the principal one being that the present survey is essentially based on village closes, whereas Dony ranged much more widely, and covered natural woodland, roadsides, and parkland.

Dony's treatment of *U. glabra* and *U. procera* is similar to that adopted here. *U. carpinifolia*, however, is split into the four species *U. carpinifolia* Gled. sensu Melville, *U. coritana* Melville, *U. cornubiensis* Weston, and *U. plotii* Druce, together with the hybrids *U. carpinifolia* × *U. coritana*, *U. carpinifolia* × *U. cornubiensis*, and *U. carpinifolia* × *U. plotii*. Reasons why these taxa have not been adopted in this series have been given earlier (Richens, 1955) and it has not proved possible to establish any simple correlation between the groups of *U. carpinifolia* sensu lato recognized in this paper and the microspecies of the Bedfordshire flora.

Perhaps the most marked divergence in treatment concerns *U. plotii*. Dony describes this as frequent and well distributed; among the localities cited for it are Dean and Shelton, which suggests that the DEAN group is assigned to *U. plotii*. There is serious objection to this treatment, since the DEAN elms lack the unilateral habit which is the prime diagnostic feature of *U. plotii*. Elm populations with the characteristic unilateral habit occur in the neighbouring county of Northamptonshire, though at some distance from the Bedfordshire border; none was recorded in the present survey.

Dony's observation that *U. carpinifolia* sensu lato is especially frequent in northern Bedfordshire is fully confirmed by the data presented here. As regards status, Dony regards all his species as native except *U. cornubiensis*. The view adopted here is that *U. glabra* alone is really native, *U. procera* and *U. carpinifolia* sensu lato being of ancient human introduction.

FAUNA

Of the insects and mites indigenous in the British Isles and known to be exclusively or mainly confined to elm, many occur in Bedfordshire. The species so far recorded are:

Coleoptera: *Hypophloeus bicolor* (Olivier), *Magdalis armigera* (Geoffroy), *Nemasoma elongatum* (L.), *Pteleobius vittatus* (F.), *Rhynchaenus alni* (L.), *Scolytus multistriatus* (Marsham), *S. scolytus* (F.).

Hemiptera: *Anthocoris gallarum-ulmi* (Degeer), *Eriosoma ulmi* (L.), *E. ulmosedens* Marchal.

Hymenoptera: *Fenusa ulmi* Sundevall, *Priophorus rufipes* (Lepeletier), *P. ulmi* (L. non auctt.) (= *P. laevifrons* Benson).

Lepidoptera: *Abraxas sylvata* (Scopoli), *Bucculatrix albedinella* (Zeller), *Cirrhia gilvago* (Schiffermueller), *Coleophora badiipenella* (Duponchel), *Cosmia affinis* (L.), *Cosmia diffinis* (L.), *Eucosma trimaculana* (Donovan), *Lithocolletis tristrigella* (Haworth), *Stigmella marginicolella* (Stainton), *S. ulmivora* (Fologne), *S. viscerella* (Stainton), *Strymon w-album* (Knoch).

Acarina: *Eriophyes ulmicola* Nalepa.

The patterns of distribution of the elm fauna, in so far as they are known, can be assigned to six categories: (1) general throughout England and, in some cases, present also in Scotland; (2) northern; (3) western; (4) southern; (5) eastern; and (6) disjunct, present in both southern and northern England but absent over considerable areas in the Midlands.

Of these categories, the second two probably represent postglacial immigrants on *U. glabra*, possibly transferring later to other species after these had been introduced. No representative of these categories occurs in Bedfordshire though the moth *Discoloxia blomeri* (Curtis), the solitary example of the western category, occurs on *U. glabra* in the Buckinghamshire Chilterns.

The southern species were most likely (1) introduced with elm setts, or in later times in unbarked timber, from the Continent or (2) they may have immigrated aerially from northern France. Either of these possibilities could account for the bug *Orthotylus prasinus* (Fallén), which though present in Buckinghamshire has not been recorded for Bedfordshire. Neither possibility however would account for the Bedfordshire sawfly *Priophorus ulmi* which, if present records are representative of the true distribution, appears also to come under the southern category. This species occurs in Scandinavia but is not known to occur on the mainland of north-west Europe. It was most probably a postglacial immigrant on *U. glabra*.

The eastern species are more likely to have been introduced with elm setts or in unbarked timber, though aerial immigration cannot be definitely excluded. At least one eastern species, *Hypophloeus bicolor*, occurs in Bedfordshire, but most, for example the beetle *Aulonium trisulcum* (Geoffroy), the jassid *Macropsis glandacea* (Fieber), and the moth *Salebria formosa* (Haworth), appear not to be present.

It is difficult to be sure how far the disjunct category represents a dearth of species in the Midlands and how far a dearth of entomologists, but since a number of species appear to be so distributed, this category is probably genuine. It is likely that the northern areas of the disjunct species represent the termini of postglacial

immigration on *U. glabra*. In some cases the southern areas may have originated similarly; they are more likely however to be the consequences of later introductions in one or other of the ways suggested above for the southern and eastern categories. Several Bedfordshire species appear to pertain to the disjunct category, for example: *Anthocoris gallorum-ulmi*, *Pteleobius vittatus*, and less certainly *Stigmella ulmivora* and *S. viscerella*, but a number of disjunct species appear to be absent, in particular, the bugs *Asciodema fieberi* (Fieber) and *Orthotylus viridinervis* (Kirschbaum) and the moth *Peronea boscana* (F.).

A last category is provided by *Abraxas sylvata*, which is generally distributed in England including Bedfordshire, though normally confined to *U. glabra*, but is not recorded for Cambridgeshire or Huntingdonshire.

It would be rash to draw any very definite conclusions from these details, but they are consistent with the view already reached that *U. glabra* is native to Bedfordshire, in contrast to its status in Cambridgeshire and Huntingdonshire, and that the other elm species have been introduced later into the county by human agency. There is nothing to suggest that Bedfordshire may have been a primary centre of distribution of either *U. carpinifolia* or *U. procera* or of any insect associated with them. The richness of the elm fauna of eastern England, in comparison with that of Bedfordshire, is consistent with the hypothesis favoured here that eastern England was the principal centre of distribution in the British Isles of *U. carpinifolia*.

HISTORY

Though there is little direct evidence of the existence of elms in Bedfordshire in prehistoric times, there is a suggestive correlation between the areas in which archaeological objects of the Neolithic, Bronze, and Iron Ages have been found and the principal areas occupied by *U. procera* (cf. Fig. 3.1 and 3.2). There appear to be two main areas of prehistoric settlement, first the Vale, especially the foot of the chalk scarp, and secondly the river gravels of the Middle Ouse. It is precisely these two areas that appear to be the primeval foci of *U. procera*. Since this species flourishes in most parts of the county, its especially high frequency in these two areas supports the hypothesis that it grew there in early, perhaps Roman times, when these areas were presumably the most intensively developed agricultural land in the county. In the third paper of this series, a Roman origin for the *U. procera* of the Icknield zone was conceded as possible, though the evidence was not conclusive for an introduction before the early Middle Ages. The above, and other evidence to be considered below, render the hypothesis of Roman origin considerably more likely.

The earliest documentary evidence normally available for the history of trees derives from place names. In the case of Bedfordshire, this evidence is only easily available in part, since the publication of the Place-Name Society dealing with the county (Mawer and Stenton, 1926) refers only incidentally to field names.

It is difficult to be certain as to what words were used for elm in early times in the county. It seems probable, however, that the word in use in pre-Norman times was *wice* (or *wic*) as in the adjoining Middle Anglian areas of Cambridgeshire,

Hertfordshire, and Huntingdonshire and probably Northamptonshire. This word was probably current over the entire county; in the south, the place name Wychhull is recorded in Luton parish in the fourteenth century (cf. Rickards, 1908). The term *wych* continued in use in the northern part of the county till at least the end of the eighteenth century; it is used in a timber survey at Sandy dated 1799. However, the term *elm*, in widespread use in Oxfordshire in the thirteenth century according to the Hundred Rolls, had come into general use in the south of Bedfordshire by the sixteenth century, where it appears to have quite replaced *wych*. It may have come from Oxfordshire via the elm-studded villages at the foot of the Chilterns. It is clear, from a Biddenham Court Roll of 1556, in which the tenants are ordered to plant 'vi ashes, okes, elmes, willowes or wyches', that, by the sixteenth century in central Bedfordshire, *elm* and *wych* were understood as applying to different taxa, presumably *U. procera* in the first case, and *U. carpinifolia* or, less likely, *U. glabra* in the second.

The significance of place names for our present purpose is further confused by the existence of the Old English word *wic* (Middle English *wyke* or *wick*), which most commonly designates a livestock farm. It persisted in use, in Luton for instance, till at least as late as the sixteenth century. In other parts of England, for example Lincolnshire and probably Essex, it appears that *wick* or its derivative *wicken* can mean elm and it is possible that the same was true in Bedfordshire. The field name Highwicks, mentioned in the early eighteenth-century glebe terrier of Shelton, for instance, might correspond to High Wyches just over the Huntingdonshire border in Kimbolton, which applies to the high elms growing there, and to the field name High Elms, mentioned in the corresponding glebe terrier for Turvey.

Turning to less ambiguous evidence, the earliest record of elm is provided by the piles under old Bedford bridge which were of iron-shod elm (Kuhlicke, private communication). This bridge may have been built in Norman or late Saxon times. Should the piles have been obtained locally, as seems most likely, this would confirm the early existence of the *U. procera* population of the Middle Ouse.

The first ecological study of a Bedfordshire wood that survives is reported in a fourteenth-century court case concerning Willington. It was claimed, in an action for waste in Sheerhatch wood in 1366, that the defendants had cut down 6,000 *ffraxinos*, 6,000 *ulmos*, 6,000 *corilos*, and 3,000 *spinas albas*. The rounded figures of this claim, with oak conspicuously absent, suggests an elm–ash wood which might well represent the primeval flora of this part of the Central Ridge. Most likely the elm was *U. glabra*. Sheerhatch wood has been extensively replanted and many exotics are now present. Several species of elm occur, especially around the edges; *U. glabra* is to be found some way in.

Frequent allusions to elm are encountered in sixteenth- and seventeenth-century documents. As regards the extreme south of the county, the Caddington Court Rolls include extensive references to the timber trees in Caddington wood, mainly beech, but in 1555 it is presented that 'Wm. Dermer de Ynyons et Edw. Preston succiderant unum ulmum in bosco domini'. Since *U. glabra* is a well-known associate of beech in the Chilterns, this is most probably the species involved.

In the Vale, a detailed survey of the timber on the copyholds in Barton in the Clay was made early in the seventeenth century. Practically every tree mentioned is elm, presumably *U. procera*. The preponderance of this elm in the local landscape has persisted till today, in striking contrast to the vegetation of the chalk scarp behind. The purchase of 'elme bordes' at Shillington, also in the Vale, is entered in the churchwardens' accounts for 1594.

Though elm is much less frequent along the Central Ridge, references to it are also found at this period. For example, 'okys, elmes, asshes and hasylls' are listed in a deed of sale concerning the parks at Ampthill in 1512. Thomas Archer, rector of Houghton Conquest, records that 'the elmes growing from the bridge to the parsonage gate wher planted by me Thomas Archer in Anno Dom. 1615 and also all the trees in the churchyard'. A little later, a rental referring to land in Husborne Crawley, drawn up around 1660, describes it as 'well wooded with elme and ash tymber and many oake spyres'. In none of these cases can one be sure as to the species concerned.

It was noted above that elms were relatively infrequent around the villages near the junction of the Ouse and Ivel, but references to elm are also found for this area. In Blunham, for instance, Sir Henry Grey undertook, according to a lease dated 1550/1, to provide oak, elm, crab, and maple for repair of the mill. In the following century, an account of the building of the vicarage at Everton enters the purchase of elm board at Sandy. In these two cases *U. procera* is the most likely species involved.

Two references have been found to the old 'wich elme trees' in Northill churchyard, one in the lease of 1678 and the other a memorandum in the parish register. One would very much like to know the species intended. Today, there is a tree of *U. glabra* growing in an adjacent garden, the other side of the churchyard wall, but of no great age. Aubrey, writing a little earlier, notes that the designation *wych elm* is used in some counties for what he calls *wych hazel* (*U. glabra*) but he does not indicate which. If one could exclude the possibility that the Northill 'wich elme' was *U. carpinifolia*, which also occurs locally though infrequently, one would arrive at the following identities for seventeenth-century mid-Bedfordshire: *elm* (*U. procera*); *wych* (*U. carpinifolia*); and *wych elm* (*U. glabra*). Since, however, *U. carpinifolia* does occur at Northill, complete confidence in these identifications is not justified.

Evidence for the *U. procera* stands around Bedford in the sixteenth century is provided by an anonymous account of the 1607 gale which records '3 score elme-trees bloune doune at the Freers, Bedford'.

In the north of the county felling of elm for building purposes at Harrold is recorded in Farrar and Boteler's building accounts for 1608, and extensive purchases for elm board for building at Hawbury Hall, Renhold, were entered in William Becher's account book in 1670–1.

Of special interest for the northern part of the county is a survey of timber in Keysoe and Thurleigh made in 1764–5. This enumerates 6,203 trees, of which 598, i.e. less than 10 per cent., are elm. Almost all the 157 closes surveyed contain oak, ash, or both; elm is very much in the minority and tends to be restricted to

particular closes and is not generally distributed. Thus, in Thos. Richardson's farm there are 325 trees in 9 closes and no elm; in Thos. Stapleton's farm 227 trees in 9 closes with 7 elms confined to 1 close; and in Mr. Gurney's farm 790 trees in 20 closes with 22 elms confined to 3 closes. Over one-third of the entire elm quota is found on one farm, Thomas Hartup's, with 683 trees in 26 closes with 228 elms distributed over 14 closes. This survey gives the impression that elm is a comparatively recent introduction into the fields in these parts, which was the impression gained during the present survey.

It is unfortunate that few records have come to hand yet dealing with the extensive late planting of elm that appears to have taken place in the central parts of the county. However, the firm of Wood and Ingram (now Laxton Bros.) of Brampton, Huntingdonshire, is known to be responsible for some of the elms at Roxton, as an entry to supply 50 large elms to 'Sr. Gileas Span Rexon', i.e. Sir Gillies Payne at Roxton, is found in Johns Wood's day book for 1 April 1770. The same firm dispatched broad-leaved elms, presumably *U. procera*, to the adjoining parish of Tempsford in 1781.

The principal traditional uses of elm in Bedfordshire are largely similar to those found in the surrounding counties. Elm boards were extensively used for waggons, wheelbarrows, and coffins, and elm was the preferred timber for wheel hubs, sheep troughs, sheep and cow cribs, and milking-stool tops (T. W. Bagshawe, private communication). Elm water mains were used in earlier times in the town of Bedford (Kuhlicke, private communication). Elm was used for beetles and flail swingles in East Anglia; in Bedfordshire, crab or other Rosaceous woods seem to have been preferred.

It is perhaps significant that two cases are on record of elm (*U. procera*) providing the stake thrust through a malefactor's corpse, buried, according to custom, on a boundary, namely Beaumont's tree on the boundary between Flitton and the chapelry of Silsoe (cf. Anon., 1945), and Jeremiah's tree on the boundary between Barton in the Clay and Streatley.

The history of the three Bedfordshire elm species thus appears to be as follows. *U. glabra* is the only native species and has been continuously present in the county since late Boreal times. *U. procera* seems to be of ancient introduction, probably Roman, the foci of distribution being the Vale and the Middle Ouse. The DEAN population of *U. carpinifolia* probably entered from Huntingdonshire in medieval times or earlier; the CARLTON population may be of similar age but is of uncertain provenance. From the seventeenth century onward, planting of elms has been extensively carried on, especially along the Central Ridge; it seems to have included forms of *U. carpinifolia* of both English and continental origin and the Dutch elm. Hybridization between *U. carpinifolia* and *U. glabra* may have occurred at various times, and hybrids from elsewhere, of which the Dutch elm may be an example, have also been introduced.

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[1] Access to this book was given by kind permission of Messrs. Laxton Bros.

THE WORLD'S FUTURE DEMAND FOR PAPER

J. J. MACGREGOR

HERE[1] we have the latest substantial study which is representative of FAO's growing emphasis on statistical forecasting. To review is difficult because, apart from the wide range of aspects covered, it is, as the sub-title declares, a study of regional trends and, as these vary widely, it is not easy to be brief. Essentially the report can be regarded as a reference book for such professional categories as policy-makers, investors, economists, and forest managers. Its individual chapters cover the method of projecting demand, aspects of forecasting, problems of meeting the future needs, and the development of trade—mainly on a regional basis.

The trend of demand. Over recent years a number of international agencies have concerned themselves with the adequacy and distribution of pulp and paper as developing countries consume more and more of 'cultural' and 'industrial' papers. Within 20 years world consumption of paper and paperboard has doubled (28 million metric tons in 1938 to 62 million in 1958). On the basis of population growth and general economic development, consumption is expected to double itself again in the next 15 years. It is believed that the world's forests should be sufficient for the additional demand likely to be posed for them, although in some parts the limit of sustained yield has already been reached and in others it is about to be reached. To produce the additional paper needed by 1975 would need roughly 280 million solid cubic metres more roundwood if pulp is to be manufactured from wood only. This represents one-third of the current fellings for industrial use. Most of the low-income countries have relied up to the present on imported paper, but importation may compete rather heavily in their expanding programmes for limited foreign exchange, and thus most countries will wish to use domestic fibre—whether from wood or agricultural residues—in order to avoid rapidly increasing import bills.

The rates of growth of demand and the possible changes in quality of paper are mentioned as being important aspects in determining the size of present and prospective markets, and in deciding whether or not certain countries will continue as exporters. It was felt that such questions had become more urgent since most forecasts have greatly under-estimated the rate of growth of requirements and of consumption within this industry. Since the war the pulp and paper industry has become one of the world's greatest activities, e.g. first manufacturing industry in Finland and Canada, second in Sweden, fifth in France, and sixth in U.S.A. Although a prosperous, expanding, industry has little difficulty in obtaining capital, the problem of matching capacity to demand is not always easy,

[1] FAO. *World Demand for Paper to 1975. A Study of Regional Trends.* H.M.S.O., 1960, 159 pp. Price 7*s.* 6*d.*

since 5 or 6 years may be involved from exploratory stage to final production. A temporary set-back, as in 1957, may lead to a situation of over-capacity, and this in turn may engender greater caution when new investment is under consideration.

World Consultation, Rome, 1959. The decision of FAO in September 1959 to convene a World Consultation on Pulp and Paper Demand, Supply and Trade, came at a convenient time since, apart from its other purposes, it provided an occasion for reviewing available information on capacity trends in relation to expected demand trends in the world as a whole and region by region, and for considering the implications for governments and industry.

The view of the FAO Secretariat papers prepared for the Consultation was that at the time there was excess capacity in the industry in relation to the effective demand even after allowance was made for the desirable marginal reserve capacity. The adequacy of capacity for 1965 was likely to be almost sufficient on the basis of existing expansion plans, although subject to many qualifications. An attempt was also made to show for 1965 tentative world and regional balances. In the report reviewed here the Secretariat's evidence has been presented as successive chapters in a unified study, with the more technical numbers relegated to appendices, and not as a series of individual papers for the Consultation.

A caution is issued that the various estimates in the report must not be regarded as forecasts of what is likely to happen in 1965 and 1975: firstly, although the techniques used have proved satisfactory they could be improved and certainly simplified; secondly, the estimates are related to certain assumptions of economic and population growth, and varying regional trends in the previous 15 years emphasize how necessary it is to be circumspect in making prognostications. It is thus preferable to look at consumption estimates as levels associated with certain stages of economic development rather than for given years. There is constant need to keep growth trends under review in order to make essential adjustments to estimates. Thirdly, while the report is probably the most comprehensive on existing capacities so far published, an accurate picture of capacity expansion plans is always difficult, and for this reason a periodic exchange of information on capacity is highly desirable.

Trade in pulp and paper. The first three chapters give the statistical and other bases for the forward estimates, and the remaining chapter provides an interesting perspective. In 1955 world exports of wood pulp and paper were 7·8 million and 10 million tons respectively, equal in value to about $2,800 million or about 3 per cent. of the total value of world trade but excluding many finished paper and paper-board products. Canada, Sweden, and Finland provided more than two-thirds of the total world export of pulp and paper; and if U.S.A. and Norway are included the proportion is more than 80 per cent. By 1947 the pre-war levels of world trade were again achieved at about 10·7 million tons and had risen to 17·9 million tons in 1957, or about 2·5 per cent. per annum. There has been a shift towards a higher proportion of paper and board which now has 57 per cent. of the total. Newsprint alone is 38 per cent. of the combined trade. The preponderant share, more than two-thirds of world exports in newsprint, is exported from Canada to U.S.A. Approximately 95 per cent. of total world exports of pulp

and paper is now, as also in the pre-war days, accounted for by North America and Western Europe. The latter has now regained some of the trade lost to North America during the war, and the two regions have about equal shares of total world exports. The growth of Canada as a provider of pulp and paper measures the determined efforts of U.S. consumers to reduce their dependence on overseas supplies. A suitable formula is used to prepare an index on import dependence (or self-sufficiency) of pulp and paper. One of the tables shows these domestic supply indices for North America and Europe, and emphasizes the marginal character of the export availabilities from these two regions and the emergence of North America as a net exporter; Canada and Scandinavia (including Finland) are the only other important net exporters within these regions. U.S.A. has reduced its import dependence while the non-Scandinavian Western European countries (excluding U.K.) have increased reliance on imports. The relevant index numbers were for 1956–7 as follows: North America (104); Canada (417); U.S. (83); Western Europe (108); Scandinavia (452); U.K. (50); and others (80).

The extent of the market for pulp and paper exports by main countries or region can be gained from the following table:

Pulp and Paper Imports into Several Regions and Areas, 1956/57
1,000 metric tons (rounded)

	Imports of wood pulp	*Imports of paper and paper-board*	*Total imports of pulp and paper*
United States. . . .	1,995	5,030	7,025
E.E.C. countries . . .	1,955	1,240	3,195
United Kingdom . . .	2,100	1,085	3,185
Latin America . . .	430	815	1,245
Remainder of Western Europe .	440	310	750
Far East	225	365	590
Africa	30	380	410
Oceania	70	275	345
Near and Middle East . .	..	95	95

This emphasizes the predominance of the U.S. for paper and board and for the total. The U.K. and the European Economic Community countries have similar amounts in the total column although the U.K. is the world's greatest single importer of pulp. Latin America as a whole is the only other market for over a million tons.

On trade prospects the report points out that in the medium term, of 5–15 years, prospects depend on rates of increase of population, and of economic growth and the extent of current and proposed expansion of production capacity. For the period beyond 1975 a number of additional factors have to be considered; the adequacy of the fibrous raw material resources in the different regions and the influence of technological changes which may widen the type of suitable raw material or alter relative costs. The Secretariat did not have the financial

resources to explore these long-range possibilities although it did recognize the relative urgency of the need to do so.

Expansion plans and future supplies of raw material. Estimates of existing and current expansion plans for each country and the outlook for roundwood supply from Europe's forests are among the useful features appearing in appendices. Between 1950 and 1957 there was a substantial rise, particularly in Sweden and France, in roundwood output from 271 to 293 million cubic metres (in spite of a decline from 65 to 49 million in Germany and in Yugoslavia): with an increase in the percentage used industrially, from 59 to 66 per cent., the 'industrial' supply rose by 32 million cubic metres; and, with a return to the position of a net importer, Europe's industrial wood consumption increased by about 30 per cent.

The felling forecasts imply that there will be a slow growth in total roundwood supplies in the decade to 1970 of about 6 per cent. but, with a decline in fuelwood requirements, industrial wood supply will increase by about 10 per cent. or 20 million cubic metres. Roundwood production per head of population in Europe is expected to decline in the coming decade but impressive increases are expected in U.S.S.R.

The forecasts indicated that the maximum production targets set out in the 1953 *European Timber Trends and Prospects*, published by FAO, were likely to be 'comfortably' exceeded. This expansion, it was recognized by the European Forestry Commission, would be inadequate if consumption trends over the past decade were to continue. However, there were certain grounds for optimism in that many estimates were conservative and had not made sufficient allowance for the flexibility in Europe's wood supply. If prices proved remunerative in 1970 it was likely that Europe would meet its requirements then. The relative costs in Europe and in wood surplus regions would determine how far increased requirements would be met by the rise in imports. The study of consumption trends and requirements—as intended by the Secretariat—would provide useful information for developing forest policies.

Report of the World Consultation. The final annex is the report of the World Consultation which took place in Rome in September 1959. Some of the special features which it covers include: an evaluation of previous techniques for demand projection; a commentary on the Secretariat's analysis of demand which had reference to national income effects (e.g. demand elasticity) and to cross-sectional (or country by country) comparisons. Factors other than population growth and income could include: technological developments affecting use of paper, or its substitutes; changes in national habits; relative price changes for paper; and government policies. Expansion of literacy on one hand and forms of protection, on the other, would have direct but different effects. The Consultation noted that estimation of the future trend of demand in Western Europe presented special problems: much of the region's capacity had been destroyed during the war, and subsequently there had been restrictions on consumption in a number of countries. At the same time, economic growth had been extremely rapid. Factors other than income growth had thus influenced the recent rise in consumption and one problem was how to measure these other factors and assess their future influence.

A Secretariat estimate which allowed for the continued but less substantial influence for these factors gives the following totals for 1965:

	Million tons
Newsprint.	4·60
Other papers and board . .	16·75
TOTAL, PAPER AND BOARD . .	21·35

This estimate was in close agreement with one which had been prepared by the pulp and paper Committee of the Organization for European Economic Co-operation based on historical trends and assuming a 3 per cent. annual rise in gross output.

The Consultation also noted that the 'natural' level of consumption appropriate to a given income level in fully planned economies like the U.S.S.R., Eastern Europe, and Mainland China might be somewhat lower than the corresponding levels in free enterprise economies. The estimate of 88 million tons and 134 million tons of world demand for paper and board for 1965 and 1975 respectively were broadly accepted. They represented a trend of lower rate than in the recent past.

Conversion factors and waste-paper recovery rates were also discussed. Existing recovery rates were expected in the regions of existing high consumption but it was expected that, with the expansion in other regions, higher recovery rates would be achieved in future.

Rated and normal capacity. The need for an internationally comparable definition of capacity was stressed and a distinction drawn between *rated* and *normal* capacity. As in other basic industries, there was need to have a margin of reserve for market stability of about 5 per cent. for both pulp and paper industries. A table showed for the eight regions details of rated capacity in 1958, current expansion plans, and estimates of future rated capacity.

Comparisons of rated capacity and production for North America and for Western Europe showed in 1958 operating ratios of 84 and 83 per cent. for newsprint, and 82 and 89 per cent. for other sectors of the paper industry; the rest of the world averaged 90 and 85 per cent. for newsprint and for other sectors respectively. Allowing for the unforeseen checks in economic growth at this time the excess capacity of 7½ million tons in world paper and board industries could more 'fairly' be represented at about 4½ million tons.

For 1965 in the current pulp and paper deficit areas of the world it was expected that the total deficit in newsprint, compared with 1957–8, would show little change and for other paper and board there would be a slight decline although the pulp deficit would rise from 450,000 tons to 1·22 million tons. If these requirements were to be met from North America and from Western Europe in the same proportion as before this would imply the following amounts for the latter in 1965: newsprint 0·06; other paper and board 0·70; and paper pulp 0·61 million metric tons. To achieve the required rated capacity, for internal demand as well, assuming an operating ratio of 95 per cent., for this level of need Western Europe would require 0·39 million tons and 65 million tons of additional capacity respectively for newsprint and for other paper and board.

It was pointed out that for paper and pulp the estimated additional requirements needed to be qualified: for example, to allow for the possibility of a transfer of the capacity for dissolving pulp to paper and pulp production. There was apparently little margin for an expansion of paper pulp facilities and only limited scope for additional expansion in newsprint and other paper and board. In addition 'changes in operating schedules' might lead to an upward revision of capacity estimates.

At first sight this view does not seem to offer any encouragement for the U.K. for expansion of newsprint and other paper and board factories, but as the estimates are made for Europe as a whole they do not discount possibilities for individual countries although it will be necessary in making forward plans to take into account the European situation as a whole. Here, of course, the operation of the European Free Trade Area or the widening of the European Economic Community would probably lead—with a reduction in U.K. protection for the board industries—to greater integration of pulp and paper production in the Scandinavian countries and a higher degree of competition in Britain. On the other hand, it would be a reasonable expectation that an extension of economic integration in Europe would lead to a substantial expansion in the rate of economic growth and thus of pulp and paper board demand.

While the Consultation emphasized the limitations of the estimates they did make clear (1) that existing expansion plans were adequate to meet the bulk of the increase in demand expected by 1965, and (2) the need to keep demand and capacity development under review. The tentative supply and consumption patterns which were summarized in a table by regions and by commodity were the most reasonable assessments it was at present possible to make.

Future of raw material supplies. On the future of raw material supplies it was noted that the long-term upward consumption trend for pulp and paper might cause local raw-material supply problems. The Consultation did examine the possibility of obtaining the likely needs of fibrous material to 1975 after making some allowance for improved utilization of long fibres and various technical developments in the pulp industry which would reduce dependence on long-fibred material by permitting greater use of short-fibred material derived from broad-leaved woods, bagasse, and agricultural residues. Such a trend would help some regions deficient in conifers.

No major problems of supply were likely to arise in North America by 1975 but in Western Europe the prospects were less reassuring, and while the estimates of the European Forestry Commission were regarded as conservative, and there was flexibility in its wood supply, the Consultation emphasized the need for intensive efforts if the longer-term requirements were to be met. This might be possible through, for example, greater use of hardwoods, mill residues, and the maturing plantations of fast-growing species.

The main types of raw material for pulping in the other regions of the world are also reviewed. Some countries have ample supplies of short fibre. The area with the greatest problems, apart from Western and Eastern Europe, are the Near and Middle East and some areas of the Far East. In view of the long-term production

period the Consultation emphasized the need to make long-term plans and urged the Secretariat to draw the attention of the forest-policy makers to the raw-material implications of the demand projections.

Scale of investment and trade changes. Industrial investment to meet the rise in regional and world demands foreseen for 1955–65 equalled an annual amount (at current prices) of more than $1,000 million per annum and in the subsequent decade would be increased by 50 per cent. These estimates exclude investment required to attain the necessary volumes of fibrous raw materials. In these periods roughly half the investment would be required in North America and Western Europe, although it was in the deficit regions that investment needs would rise most rapidly. In view of the limited capital resources available in developing countries there was thus scope and need for investment from overseas.

Many of these 'deficit' regions have made determined efforts to increase their domestic production of paper: Latin America, Africa, the Near and Middle East, the Far East excluding Japan, and Oceania have all shown substantial decline in paper imports as a percentage of consumption. Yet net imports into these regions had risen by 40 per cent. to 2 million tons in the past decade while net pulp imports had more than doubled to over 600,000 tons. Exports from the U.S.S.R. and Eastern Europe were more or less balanced by imports and information available to the Secretariat suggested that net exports from these countries were not likely in the coming years to affect world markets in view of their own rapidly rising demands. The total level of world trade in wood pulp in 1958 was 7½ million tons compared with 4½ million tons 10 years earlier and 5½ million tons before the war. For paper and board the corresponding amounts were 10½, 6½, and 6 million tons.

Need for continued study. Several members of the Consultation felt that the current trends towards economic integration in Europe and elsewhere might eventually lead to significant changes in the trade flows described in one of the Secretariat's papers. Participants from the E.E.C. and E.F.T.A. countries pointed out that the arrangements proposed, or in being, were not intended to lead to 'closed economies' but rather to serve as a step towards an expanding world trade. The process would be accelerated by the growth promoted through economic integration, and the progress towards such integration was one of the aspects which it was thought worth while to review from time to time. The discussion had exposed a number of other problems which called for a periodic international consultation and continued study. It was argued by the Consultation that appropriate provision should be made for strengthening FAO's already substantial study of pulp and paper and that it should co-operate with other national organizations, and representatives of the industry.

Perhaps this report was not the forum in which the prospects for individual countries could be assessed in any detail, but it would have added considerably to the interest of readers of *Forestry* to know what the prospective influences of the regional groupings of the E.E.C. and of E.F.T.A. were likely to have on individual countries including the U.K. Apart, therefore, from the level of pressure on supplies of raw material, we may have to wait a little longer before a

more exact idea of Britain's problems and place can be defined. In this connexion it is worth noting that the Advisory Committee recommended by the Consultation has been set up and has met twice; and that FAO is now carrying out a more detailed study, with the help of a Trust Fund, of trends and prospects in Europe which may be completed by the end of 1962. The crux of the problem is what will happen in the years 1975–2000 and the Secretariat shared the Consultation's view on the need to look ahead.

The concluding paragraph of the Foreword to the report is perhaps a fitting ending for its review:

> But with all these qualifications, it is believed that the pages which follow, in which forward estimates have been used for exposition rather than for prophecy, may help governments, development authorities and industries in the preparation of their medium- and long-term plans for developing the pulp and paper sector. At the same time the trends revealed in this study—whether the projected levels of demand are reached sooner or later than the years indicated—will give foresters a measure of the challenge that lies ahead of them if they are to provide this important and expanding industry with the raw material it will need.

REVIEWS

Silva Fennica 105. Symposium on Forest Types and Forest Ecosystems during the IX International Botanical Congress, Montreal, 24th August 1959. Helsinki, 1960. 142 pp.

Review by E. W. Jones

THE classification of forest communities has been much discussed recently; the discussion was perhaps started by Sukachev at the World Forestry Congress in Dehra Dun in December 1954, and has been continued at every available International Congress since then, but there had already been heated and prolonged discussion about the classification of plant communities amongst botanists (to whom, of course, forest vegetation is merely a special case of vegetation in general) at their Paris Congress in July 1954.

A joint symposium by foresters and botanists was held at the Montreal International Botanical Congress; the eighteen short papers there presented are here printed in full, together with a report of the discussion and a late contribution by Dr. R. Tüxen. Four of the contributions are in German, one in French, and the remainder in English.

Some of the contributors are practitioners in one form or another of vegetation-classification. Ellenberg and Tüxen—both botanists—are pillars of the Braun–Blanquet school; Scamoni and Aichinger—both forester-botanists—represent schismatic elements from that school. Kujala (forester) and Kalela (botanist) speak for Cajander's forest types; Sukachev and Hills are advocates for their own systems. Naturally such authors tend to try and justify the general utility of their own procedure, and on the whole the more balanced and critical views come from other sources.

Most of what is said in these papers has been said elsewhere, some of it *ad nauseam*; their interest lies more in the sidelights which they throw and the features which they emphasize than in fresh ideas. On this account a 'Review' must consist mainly of personal impressions.

Three papers seem to me to be outstanding for their clarity of thought—those by Daubenmire, Kalela, and Rowe. Daubenmire (without mentioning any names) administers some well-deserved criticism of some of his American colleagues who see 'continua' (vegetation-complexes in which there is continuous variation—in space—in specific composition, with no segregation of definite 'associations') in all the 'ecosystems' which they study; readers who have not studied the methods of the 'continuum' school will not appreciate the force of his remarks. Other contributors accept the 'continua' as real; but Ellenberg is surely overlooking one of the chief differences between the classification of living organisms and that of vegetation when he merely remarks of 'continua' that the difficulty presented by intergradation is one 'which besets all investigators who are concerned with living things' (my translation). For this intergradation is normal between plant communities, as it is also between soil series, climatic types, etc., while it is exceptional between species, genera, and families—otherwise the systematic study of plants and animals as we know it would never have been possible.

Rowe points out the logical fallacy in the constantly repeated argument that the plant-cover is the expression of the environment, so that by grouping together areas with identical plant communities we should be grouping together areas with biologically equivalent environments.

There seems to me to be a strong tendency with some of the authors to overlook the real practical difficulties of classification; they state their creed in highly abstruse terms, and then consider the ceremonial details—as, for example, whether foresters should use Latin names—as the only matters which deserve discussion. This, of course, is a slight exaggeration, but the tendency is there. It is all very well to say, with Sukachev, that all the members of a single forest 'biogeocoenose-type' should be identical in flora, fauna, and environment, or with Scamoni, that all members of a forest type have 'the same environment, the same vegetation and the same fauna, they also have the same developmental tendencies and require the same silvicultural treatment'. These are idealistic statements; the practical difficulty is that scarcely any two forest stands really are absolutely identical in all these respects; there must be more or less subjective decisions as to what constitutes 'sameness'—on the relative importance of various species, of various environmental factors, and of flora and fauna. These, not the philosophic concepts, are the difficulties and, as Kalela points out, they become greater the greater the area over which we extend our classification.

There seems to me also to be a tendency to overlook the question of the utility of a classification. One or two contributors—most conspicuously Rowe—clearly state that the nature of the classification should be dictated by its purpose. Ovington and Linteau talk of the classification indicating levels of productivity—a purpose, however, for which forest types have in fact often proved unsuitable. We are told that the Braun–Blanquet system has been 'successfully used' (that is J. J. Barkmann's phrase) in various tropical countries. But the test of success is not that a phytosociologist should be able to produce descriptions of what he believes to be 'associations', but that the units which he has recognized should be recognizable by others, and that they should prove useful by, for example, deepening our understanding of the vegetation, or proving reliable guides to its behaviour. The same criticism applies to Hills's table of Ontario's forest types; it is not the construction of such a table, but its utility, which shows the value of the procedure, and of this utility we are given little proof.

There was a very general recognition of the contrast between the methods which lay most emphasis on vegetation and those which lay most emphasis on environment as the basis for classification. It was also very generally recognized that the difficulties of classifying vegetation became greater the more disturbed it has been. Hills's system in Ontario is the chief example which illustrated the environmental basis: Hills himself, in the discussion, denied that his system was of this kind, but the arguments which he used in refuting the allegation seem to me to prove its truth.

The upholders of the Braun–Blanquet school, in their anxiety to prove its universality, claim that they do not neglect the environmental factors, that they base their classification on the whole of the vegetation and not on certain selected species, that they *do* give weight to dominants. Ellenberg argues that their units come to the same thing as the forest types of the Finns and Sukachev's 'biogeocoenoses'. I am aware that there have recently been considerable changes in the practice of the Braun–Blanquet school, particularly with regard to their treatment of dominants, and it is easy for one who has not been brought up in its doctrines to misunderstand them; yet if I understand them rightly, these arguments overlook certain important facts. Some weight may be attached to environmental factors, but from the fact that one subassociation of an association may occur on basic soils and another subassociation on acidic soils, it is obvious that this weight is very little. When one subassociation of an association is suitable for growing poplar, and another only for growing Scots pine (which, according to Passarge, is the case in the Querceto-Carpinetum), there cannot be much 'sameness' of environment throughout the association. One

member of the school (Meusel) has even criticized his fellow members for making vegetation units too consciously to coincide with soil types. If I understand the methods rightly, the vegetation units are defined purely floristically without any thought as to either their origin or their utility. If a unit should coincide with a particular environment, it is not because the environmental factors have been considered in defining that unit. Similarly, successional status is neglected; an association represents neither any particular phase in succession nor any group of successionally related communities. These are major differences from Sukachev, who would give equal weight to vegetation and environment, and from the Finnish forest types, whose units *are* successionally related communities defined by a common climax.

Aichinger tells us how he came to reject the Braun–Blanquet technique for the purposes of practical forestry. He used to teach it to classes of foresters, but despite the interest which he aroused, the 'expected results' in forestry practice did not follow. 'I carefully prepared the practical classes in advance and sought out stands which were conspicuous for the abundance of characteristic species. Thus the participants were stimulated by the significance of characteristic species as indicators of definite forest communities. . . . But when the participants went back to their own forests, they could not find the same conditions' (my translation). Here, I believe, Aichinger has indicated one of the great weaknesses of the Braun–Blanquet school—it has been too selective. A system of classification may seem quite feasible so long as it is based upon and is applied to what the classifier chooses to regard as 'typical' material, but may be quite impracticable if it has to be applied to all the material which Nature presents to us.

This symposium was doubtless worth while; the Forest Society of Finland who have published it in order to commemorate the 50th anniversary of Cajander's classic essay on Forest Types, and Professor L. Heikurainen who has had the difficult task of editing the volume, have carried out a useful job.

PHILIPPE DUCHAUFOUR. *Précis de Pédologie*. Masson et Cie, 120, Boulevard Saint-Germain, Paris VI^{e}, 1960. Pp. 438 with 62 figures and 16 plates of which 2 are in colour. Price 61 NF.

Review by E. A. FITZPATRICK

FOR many years there has been a need for a comprehensive book on soil science which embodies the principles and concepts of the subject but yet is of sufficient simplicity to be suitable for students in their first year. This need has now been well satisfied in the publication of this book by Professor Duchaufour.

On first quickly turning over the pages one is impressed by the large number of excellent illustrations, quality of paper, and layout, one of the main attractions being the frequent headings and short paragraphs. This together with the full Index and *Tables des Matières* situated at the very end of the book makes for easy reference, a feature sometimes overlooked by authors who forget that students are often in a very great hurry to find information.

Throughout the text Professor Duchaufour has succeeded in presenting soil as a dynamic body capable of profound changes. This is largely achieved by the early introduction of the concept of soil evolution which is developed and amplified later. The book is divided into three parts: The properties of soil; Genesis and evolution of soils; and Applied pedology.

The properties of soil are given in a simple and straightforward manner which is ideal for the young student. Admirable though this may be, there are occasions when one feels

there has been over-simplification which is misleading and may even be inaccurate. For example, on page 47 it is stated that the permanent wilting percentage is obtained by multiplying the value obtained from the determination of hygroscopic moisture by the factor 1·5. This may be true for many cases, but it is by no means universally true. Again, after a correct definition of pF has been given on page 48, it is later equated with force.

In the chapter on the chemistry of soil, more detail in a number of places would have greatly improved this section. Not enough is said about the role of the micro-elements, nothing being said about the toxicity of the elements when present in excessive amounts. However, the inclusion of a separate chapter on the role of Iron and one on Oxidation-reduction potential is an interesting innovation, particularly for the junior student.

The importance and complexity of soil organic matter is made perfectly clear by giving attention to its chemical properties as well as its morphology in the field. This very necessary duality of approach is frequently encountered and is clearly given in the chapter on the methods of studying profiles in Part three.

The second part of the book on evolution and genesis is really outstanding and should be welcomed by all teachers of the subject. Students should find the concept of soil climax and soil evolution both interesting and stimulating. Soil classification has always been a controversial subject and in any discussion of the matter emotions are soon aroused. The system of classification used is that put forward by Aubert and Duchaufour and may be considered as a good, simple expedient for young minds, but like all systems of soil classification has its shortcomings. The discussion of the soils is good, and of particular interest and importance are the attempts to show in diagrammatic form evolutionary changes and relationships which exist between many of the soils. Here again, however, there could with profit be expansion in some places. Physical weathering is dismissed in ten lines. More could have been said about saline soils which occupy large areas of the earth's surface and represent a very large potential area for crop production. There is one feature that may lead to confusion and that is the use of the terms 'lessivage', 'sols lessivés', and the 'horizon lessivé'.

Part three starts with a consideration of soil erosion and is followed by amelioration and, finally, mapping, field and laboratory studies. Although the last section is adequate the treatment of erosion and amelioration is somewhat thin.

Finally, there is an appendix of standard analytical methods and a Bibliography. Throughout the text constant reference is made to various papers and books by a number of authors. The Bibliography shows a predominantly European bias and there are many outstanding works which are not mentioned. A notable omission is *The Katamorphism of Igneous Rocks under Humid Tropical Conditions*, by J. B. Harrison.

The criticisms given above are not intended to detract from the high quality of this work, which should find a place in the library of all those connected with soil science. It can be strongly recommended to all first-year students who are able to read French.

L. Parrot. 'De la variabilité génétique de la densité du bois chez l'Épicéa (*Picea excelsa* Link.).' *Annales de l'École Nationale des Eaux et Forêts et de la Station de Recherches et Expériences*. Nancy, 14, Rue Girardet, 1960. Volume xvii, Part 3. Annual subscription 50 NF.

Review by C. W. Scott

THE paper describes wood-density determinations by Pressler borer on some 800 living trees of *Picea abies* of 26 provenances, all growing near Nancy, about 22 to 26 years

old. The provenances include 6 from the French Juras, 7 from Poland, 1 from Lithuania, and 12 from an international series covering Finland and Norway to Bulgaria and Yugoslavia, and much of Central Europe other than Germany. Some 25 to 52 trees from each provenance were sampled by borer at 4 ft. 5 in. above ground, in 2 borings per tree east and west, giving about 1,600 cores. Statistical standards and procedures were applied throughout.

The chief results were as follows:

1. Highly significant variations in average wood density were shown by various provenances.
2. No correlation was found between wood density and latitude of provenance.
3. There was very little correlation between wood density and rate of growth, so little as to be considered negligible.
4. Individual trees within a given provenance showed a marked variation in wood density from the average for that provenance, justifying individual selection. Rapid growth and high density of wood are sometimes combined in a given tree.

The author considers that the results suggest that in tree breeding the rate of growth should be a main criterion, and the wood density a secondary criterion, because the former shows more variation than the latter.

H. Arthur Meyer, Arthur B. Recknagel, Donald B. Stevenson, and Ronald A. Bartoo. *Forest Management.* 2nd edition 1961. The Ronald Press Company, 15 East 26th Street, New York, 10. Pp. 282, illustrated. Price $8.50.

Review by N. V. Brasnett

THIS book is a revised edition of that by Meyer, Rechnagel, and Stevenson, 1952, the senior author of which, late Professor of Forestry in Pennsylvania State University, died in 1955. A. B. Recknagel is Forestry Consultant to the St. Regis Paper Company; D. S. Stevenson, formerly a Research Adviser in Forestry in the U.S. Department of Agriculture, is now Chief Forester of the Buckeye Cellulose Corporation, and R. A. Bartoo, the new-comer to the team, is Associate Professor of Forestry in the Pennsylvania State University.

The size of the book remains very much the same, but the text has been completely rearranged to consist of a short Introduction, four Parts, and an Appendix. Part I, Organization of Forest Property for Management, consists of thirty-five pages covering the concept of sustained-yield management, the mapping, subdivision, and classification of forests, the determination of growing stock, growth, &c. Part II discusses the structure, growth, and growing stocks of even-aged and uneven-aged forests, and methods of determining and distributing possible yields, in one hundred and fourteen interesting pages. Part III, Management, of thirty-eight pages, describes the preparation, control, and revision of management plans, and the business organization of a forest property. Part IV compresses the History and Present State of Forest Management into eight pages.

All this is very much what would be found in any textbook on the subject, except that the numerous examples and tables of data are from United States forests of various types. It is presented in a concise, clear, and practical manner in keeping with the wide experience and knowledge of its authors. The form of contents recommended for a full-scale management plan scarcely differs from that of, say, an Indian working plan. At the end of each of the ten chapters there are lists of references and of suggested supplementary reading. The

literature cited in these is, naturally, predominantly North American, but European writers are not completely neglected.

For British readers the Appendix of sixty-three pages will be the most interesting part of the book. In this are given the outlines of four American management plans (three new to this edition):

1. The introduction of management on a small holding of 150 acres with a selection salvage cut and prediction of a smaller but steady output every tenth year.
2. Introduction of sustained yield management on 49,000 acres of heavily cut-over land belonging to a lumber company by a preliminary plan in 1943 with a report on progress in 1953.

   The Company has been convinced that sustained yield and the installation of machinery to process small-dimension products from inferior hardwoods, previously ignored in the harvesting of pines, is profitable. It has now acquired 34,000 more acres to be included in a revised plan for selection working of the improvement-felling type laid down in the preliminary plan.
3. Summary of a hundred-page plan for some 700,000 acres of National Forest, divided into 125 compartments, managed since 1912. The 1946 revision calculates allowable cuts for five groups of species, mainly by clear-felling controlled by area and volume. 'Since operating and marketing conditions may not permit cutting precisely at the rate specified in the table, the rate for each sawtimber category listed above and for other products may be exceeded by not more than 25 per cent in one year, providing the total cut in a 10-year period is not exceeded by more than 5 per cent. Under cuts may be accumulated by decades or until the plan is revised, but liquidation of any accumulation will be subject to the 25-per-cent-overcut limitation.'
4. A plan for a 220,000 tree farm belonging to a match company. 'Old growth and excess stocking of smaller-sized trees' will supply the bulk of the steady annual yield 1958–70. The same yield can be harvested annually, half from old growth and half from second growth till 1980, after which there will be a higher annual yield from second growth only during the next decade. From 1902 cutting on the Company's land (then 40,000 acres only) was based on diameter limits, but for the last 15 years careful selection marking has aimed at leaving healthy young trees for future crops. 'The marking tends to result in group selection within small areas of mostly an acre or less.'

Forest management is naturally a later development in America, where 'the low values of forest products have hardly justified intensive management until recently', than in Europe, but it appears to be following very much the same course. 'The establishment of forest management after years of forest exploitation is a gradual process. . . . After the establishment of fire prevention, improvement cuttings and plantings may be followed by small-scale cutting operations on the better-stocked areas of the forest. At this stage of forest management elaborate plans are not needed. As soon as the need of planned management is recognized, it is nevertheless important that the general course of action be outlined in a preliminary management plan. . . . Each subsequent revision of an original management plan will embrace new areas of forest activities, and the preliminary plans will assume more and more definite character and form.'

In an interesting chapter, The Forest as a Business Enterprise, the authors stress that 'No private forest enterprise will consider forest management as an integral part of its activities unless it is profitable'. They agree, however, that 'Certain forests in public ownership may not be capable of yielding annual net returns; yet their management may be fully justified by the indirect benefits (or profits in a wider sense of the word) which are

derived from these forests'. They point out that in the management of such forests 'the daily problems of the manager are much the same as those of a manager in charge of an industrial forestry enterprise . . . to reduce to a minimum the financial deficit which must be covered from other sources of income'.

In the same chapter there appears a warning about the keeping of records. After stressing the importance of cost accounting and cost analysis the authors point out that in many industrial enterprises there are separate accounting departments. 'The accountant is not sufficiently familiar with the field work of forest management to know what detailed information of costs is important to the manager. Similarly, few foresters are well enough versed in accounting to be able to influence or to change accounting procedures in order that they will better serve their requirements. The situation frequently leads to the establishment of separate control units and cost records. Such a duplication of effort is unwarranted and can be avoided if the technical forester receives the necessary training in business management and accounting to enable him to understand the accounting methods of a business.'

It is a pity that the price of this interesting and well-produced book will be likely to restrict purchasers of it in this country to the libraries of universities and training schools.

OLAF HAGERUP and VAGN PETERSSON. *A Botanical Atlas.* Volume II. Mosses, Ferns, Conifers, Horsetails, Lycopods, Phylogeny. English Translation by H. Gilbert-Carter. Ejnar Munksgaard Ltd., Copenhagen, 1960. Pp. 299, 8 inches by 11 inches. Price Dan. Kr. 76.

Review by A. CARLISLE

WHEN this book is opened for the first time, the reader finds that it does not contain what the title has led him to expect. The term 'Atlas' is generally associated with a volume of maps, and most botanists would expect a Botanical Atlas to show the distribution of plants in a particular geographical region. In fact, this book is a collection of drawings of Danish plants. Once the reader has recovered from this initial surprise, however, he will be struck by the quality of the drawings which are of a very high standard.

This book is the second volume of a major work, the first of which treats the Angiosperms in a similar manner. This second volume is concerned with mosses (including the *Sphagnaceae*), liverworts, the *Hydropteridales*, ferns, horsetails, lycopods, the *Selaginellaceae*, the *Isoëtaceae*, and the conifers. Although only Danish species are shown, many of these occur in Britain. There are illustrations of about half the Danish mosses and liverworts, and of all the species of the other classes of plants. A short text gives the name of each plant, the authority, a synonym, and the scale. In addition, there are introductory notes on the morphology, anatomy, and reproduction of each of the major classes of plants, and a chapter on phylogeny. Finally, there is a short bibliography and an index of plant names.

The text, which is brief and to the point, is written in both Danish and English and contains a great deal of fundamental information which will be of great use to a student who wishes to learn about the morphology, reproduction, and life history of the plants without having to consult the more formidable textbooks. It is written in a scientific manner, and is only occasionally marred by sentences such as 'Whence can have arisen the glorious green mantle which adorns our planet . . .?', which may, however, read better in the original Danish. The book is very well produced and there are relatively few errors.

The illustrations of the mosses and liverworts occupy more than half the book.

Mr. Hagerup has managed to give depth to his drawings, which give an excellent idea of the habit and texture of the plants. Most of the British moss and liverwort floras describe the habits of the plants in the text but do not illustrate them, leaving much to the imagination of the reader. These drawings by Mr. Hagerup fill this gap, and will be of value to bryologists as a supplement to the more detailed keys and descriptions. The illustrations would have been of even greater value if a diagram of the details of the leaf anatomy of each species could have been included.

The illustrations of the ferns, horsetails, lycopods, and conifers, by Vagn Petersson, are also very fine. The drawings of the ferns emphasize the leaf and pinnule shape. Although this is a useful diagnostic character, details of the sori would also have been useful.

The bibliography consists mainly of references to the mosses and liverworts, and there are no references to standard descriptions of the other plants illustrated in this volume. In a book of this type an extensive bibliography would be out of place, but the list of references could have been profitably extended to cover descriptions of all the major classes of plants.

This most attractive book will be a welcome addition to the bookshelves of any botanist, forester, or naturalist, both on account of the great beauty of the illustrations, and because of its value as an aid in identifying the plants.

P. d'A. Jones and E. N. Simons. *Story of the Saw.* Newman Neame Limited, 50 Fitzroy Street, London, W. 1. 1961. Pp. 80. Price 21*s.* net.

Review by A. H. Lloyd

THIS very attractive and splendidly illustrated book has been published to mark the second centenary of the world's oldest sawmakers, Spear & Jackson Ltd. It describes in detail the evolution of the saw, from the small primitive flints used in prehistoric times to the latest machine-saws of 1960. Ninety-four drawings and photographs are used to illustrate this long progress, from the Mesolithic flints to the world's largest saw, 12 feet in diameter, cutting huge blocks of Portland stone in Dorset.

The extensive research required for this historical record of a difficult subject was undertaken at fourteen different science museums, libraries, and universities, with the help of the various staffs. The Museum of English Rural Life, at Reading, provided some of the photographs of early British saws.

The story begins with Neolithic man, half a million years ago, holding in his hand a jagged flint saw a few inches long. A very long period passed before the flint was mounted in a bone or horn handle. During this period, near the sea shores, sharks' teeth and the long jaw of the sawfish were also used for sawing.

The earliest recorded metal saw was of hardened copper, in about 4700 B.C., and was used in Egypt for cutting coffin-boards, and by 1450 B.C. bronze saws were in use. Saws are mentioned early in the Bible for stone-working and also for sawing various gentlemen asunder, and this gruesome process is well illustrated on page 21 of the *Story of the Saw*. The Iron Age (from 500 B.C.) brought a great advance in saws, not only in materials but also by the introduction of the frame-saw. The efficiency of the saws was greatly improved by the Romans, who introduced the swaging or expanding of the tips of the saw-teeth to widen the saw kerf and reduce friction. Improvement was also effected by bending alternate teeth to the right and left, and both of these methods are, of course, still used today.

From the fifteenth century onwards, the chief developments in sawing have been in the machinery which moves and controls the saws, and the invention of the steam engine naturally gave great stimulus to all woodworking machinery. The simple manually

operated pit-saws are still widely used in Africa and the East, especially where the sawn timber is needed near to the site or in small quantities.

The first circular saw was invented by Samuel Muller at Southampton in 1797, but Walter Taylor, in the same city, claims to have made the first circular sawmill machine. As these saws cut by continuous rotary action, instead of the slower reciprocal movement of the frame-saw, the output was naturally increased. This change was revolutionary and led eventually to the invention of the bandsaw, with a similar continuous action. In the meantime, the use of circular saws of large sizes rapidly extended all over the world, and during the past 30 years the various types of inserted-teeth circular saws have been widely adopted.

Although the first band-saw was invented in England, by Newberry in 1808, this important invention was not at first followed up in Great Britain, probably owing to the lack of suitable steel. In 1846, in France, Mademoiselle Crépin, 'a lady with mechanical proclivities of no mean order', took out a patent for her own version of Newberry's band-saw of 38 years earlier, and France has apparently developed the various types of band-saw ever since. This is particularly noticeable with the French portable band-saw mills of all sizes, down to the small foot-pedal driven band-saws used for cutting up firewood in the streets. The final section of the *Story of the Saw* deals with the latest types of saws and sawmills of 1960. The numerous saws described are well illustrated and are divided into two categories, reciprocating and continuous-action sawmills. Both these types are manufactured in Sheffield and full details are given of the latest developments and new equipment for sawmilling.

The book is so well written, and the illustrations so attractive, that it will appeal to historians as well as to engineers and all interested in the conversion of timber in any form.

ROGER F. ANDERSON. *Forest and Shade Tree Entomology*. John Wiley and Sons Ltd., Gordon House, Greencoat Place, London, S.W. 1. 1960. Pp. 428, illustrated. Price 68*s*.

Review by MYLES CROOKE

THIS textbook has been written primarily for use by American forestry and entomology students. It is divided into two sections, the first dealing with the fundamental principles of insect structure, physiology, development, classification, ecology, survey, and control; and the second covering the biology and forest relationships of the more important forest insect species and the control methods currently available for use against these species.

The first section is compressed into the space of 91 pages. It is neatly written and will probably provide a convenient and easily digestible snack for the readers to whom it is addressed; but the condensation is such that it can have no wider field of appeal or utility.

The second section describes in considerable detail the appearance, life cycle, distribution, and tree hosts of a large assembly of North American forest insects. This part of the work should prove of great value not only to students but also to practising foresters on the American continent, since it contains many easily worked keys and large numbers of quite adequate photographic illustrations. From these, used in conjunction with the text, it should be a simple matter to carry out identification of the majority of forest insect species in America, particularly since, throughout, stress has been laid on those characteristics which are readily observable in the field. For this reason alone one feels confident that this book will be well received and frequently consulted.

Quite apart from considerations of price, however, it is unlikely that this volume will

establish any sort of place for itself on the bookshelves of European readers. For the forester, the subject-matter is geographically too restricted to be of value, whilst, for the entomologist, the superficial treatment of general topics will send him elsewhere for information.

OBITUARY

PROFESSOR ÉTIENNE HUBAULT

THE sudden death in April 1961 of Professor E. Hubault at his home at Mosnes will be a great loss to forestry. Since the end of the war, in 1945, he has organized annual visits to French forests for university students, chiefly from Aberdeen and Oxford. He often accompanied the students and his good knowledge of English enabled him to help them with linguistic difficulties and with forest entomology. Professor Hubault was a Doctor of Science and for many years lectured in zoology at the State Forest School, at Nancy. He published many articles on his subject and specialized on the flora and fauna of the Lakes of France. At the beginning of the Second World War, Professor Hubault at once offered his services to the army and gave invaluable help in organizing timber supplies. In 1940 he stayed with the British Army until the last boat-load of troops left St. Malo, and luckily escaped through the German lines back to his home on the Loire. He won the *Croix de Guerre* in the First World War and was appointed *Officier de la Légion d'Honneur*. He also held many academic honours in his own profession. Professor Hubault always seemed to understand the idiosyncrasies and peculiarities of the British but still liked us.

All of us who knew him will wish to express our deep sympathy with Madame Hubault in her great loss.

A. H. L.

BERNARD ALWYN JAY

B. A. Jay, M.A. For. (Cantab.), F.L.S., A.R.P.S., Deputy Director, Timber Development Association, died in July 1961 aged 50 years.

Jay joined the T.D.A. in 1936 and had been Deputy Director since 1952 and in charge of the Research Laboratories at Tyler's Green since they were opened in the same year.

Jay had wide interests. He compiled a number of the 'little red books' published by the T.D.A. and was co-author with E. H. B. Boulton of *British Timbers*. In 1952 he published his *Conifers in Britain* in which as botanist and photographer he aimed to provide a guide to identification based on differences in foliage and illustrated these differences with 136 splendid photographs. He was a Fellow of the *Institute of Wood Science* and editor of its journal since its beginning in 1958, setting a very high standard indeed. He had long been a Fellow of the *Society of Foresters*.

He was very able but characteristically modest and friendly, and his early death is a great loss to timber science and forestry. He leaves a widow and three children to whom we offer our sympathy.

We regret also to record the deaths recently of Mr. W. E. Hiley, Professor Mark Anderson, Sir Samuel Strang Steel, and Mr. B. B. Osmaston.

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